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WAYNE KERR TESTMATIC A60

MP MASTER
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PROGRAMMING MANUAL

Wilmot Breeden Electronics

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TESTMATIC A60

Addendum to Programming Manual, TP78/3

Do not use Test No. 00 if it is proposed to use a printer with the A60. When a print-out is required, Test No. 00 should be programmed 'Reset' and measurements should start at Test No. 01.

February 1976

WAYNE KERR

TESTMATIC A60

PROGRAMMING MANUAL

TESTMATIC A60

Second Addendum to Programming Manual TP78/3

Page 92 Measurement Accuracy. Add:-

ication is TP78/3

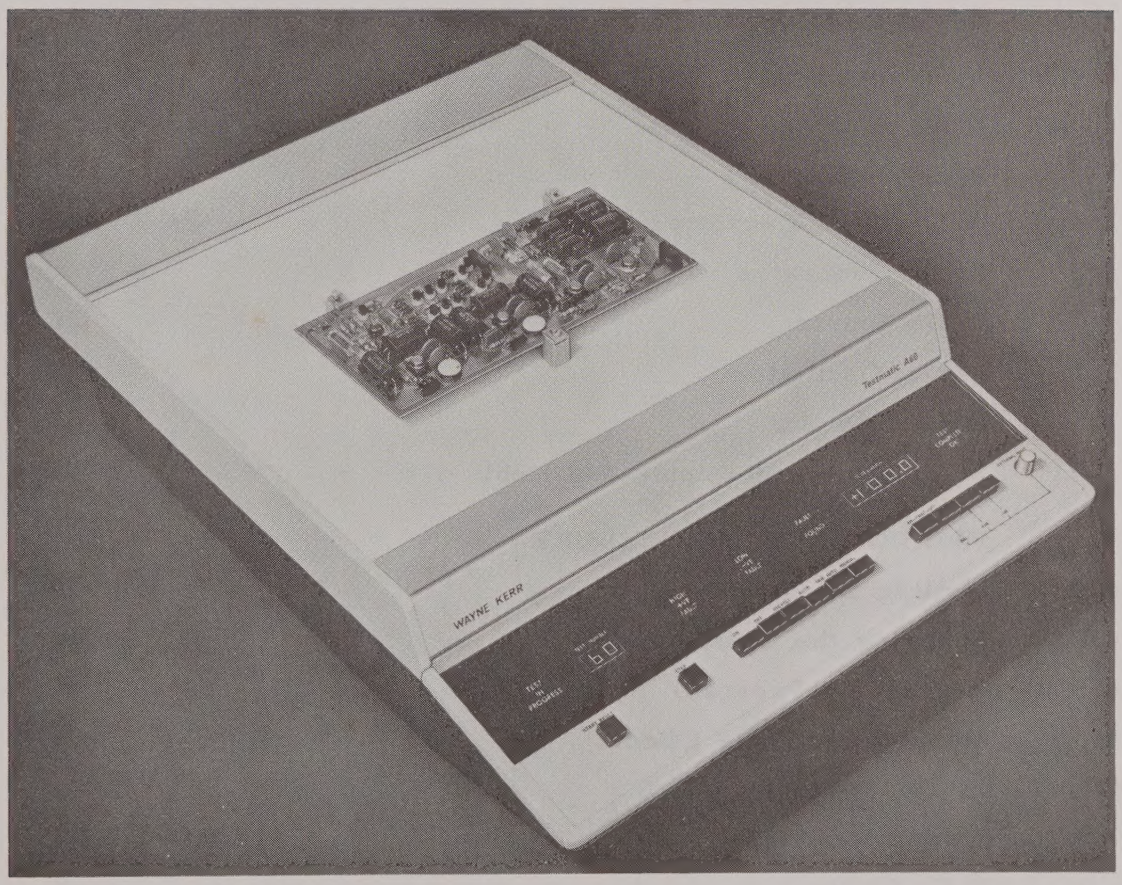
Temperature coefficient of virtual earth:

$\pm$ ± 30μV per °C.

October 1976

WILMOT BREEDEN ELECTRONICS

Ferrograph Rendar Wayne Kerr


WAYNE KERR
Testmatic 440
TEST IN PROGRESS
60
+1000

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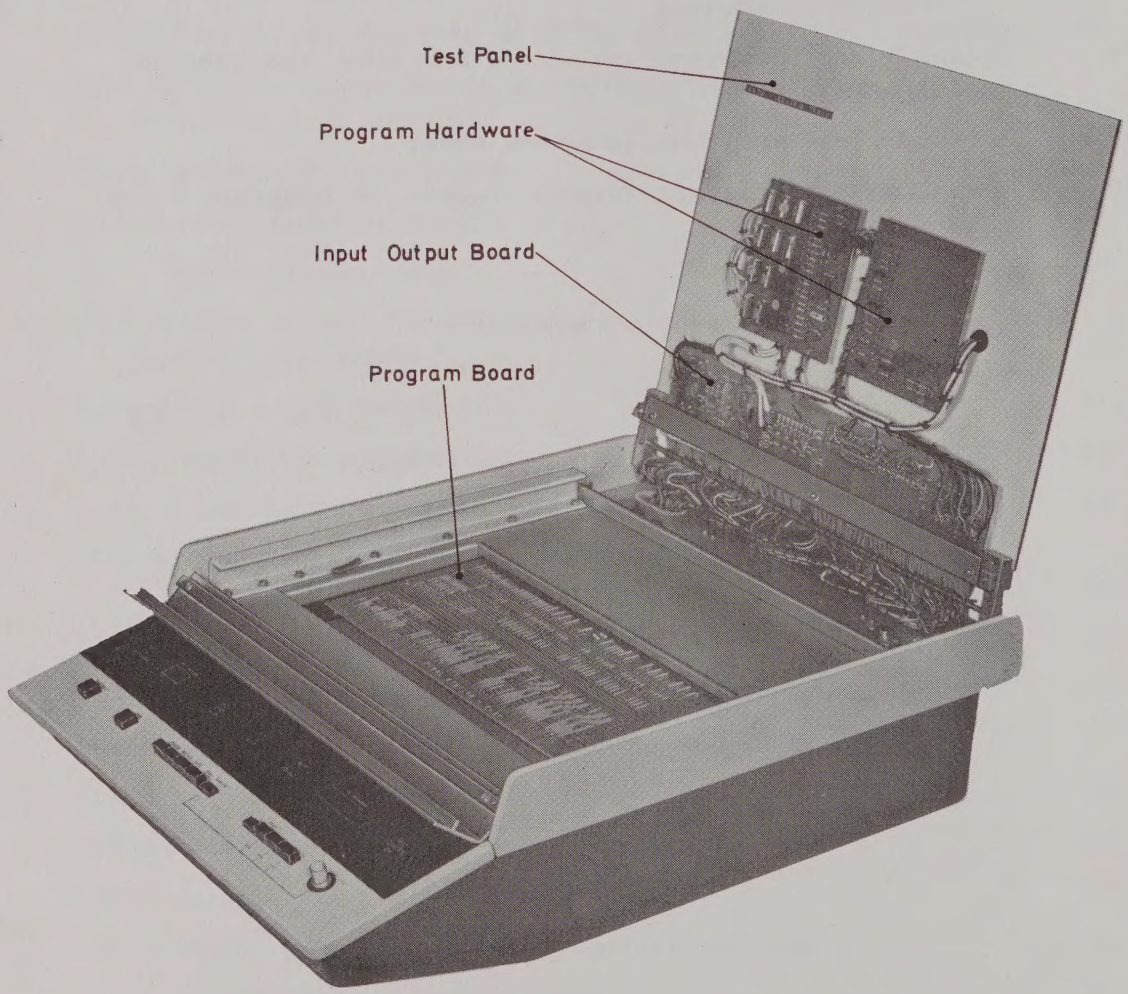


FIG. 1 TESTMATIC A60

1.0 INTRODUCTION

The Testmatic A60 makes a rapid and automatic series of up to 60 d.c. and a.c. measurements on printed circuit boards and other electronic sub-assemblies, the measurements being to pre-determined pass/fail limits set individually for each test point.

The unit under test is mounted on a removable test panel, which is equipped by the user with the necessary mounting hardware, connectors and spring-loaded contact pins. The various test facilities and parameters are selected by connecting wire links, diodes and resistors on the Input/Output and Program printed-circuit boards, which are removable and easily accessible beneath the hinged test panel (Fig. 1).

Kits comprising test panel, input/output and program boards, contact pins and diodes, are available from Wilmot Breeden Electronics so that complete alternative hardware programs can be prepared and rapidly interchanged for testing units of different types.

This aspect of the A60, that all programming is carried out on instantly-interchangeable sub-assemblies while the basic instrument remains in its standard form, makes for great flexibility in operation. Any program may be inserted in any machine and out-time and servicing difficulties are minimised.

The main facilities offered by the A60 are summarised briefly below.

i) Measurement of d.c. voltages from 5mV to 500V, by insertion of appropriate series resistors in hardware program.

ii) Measurement of a.c. voltages from 5mV to 500V by use of built-in a.c./d.c. converter.

iii) Selection of pass/fail tolerance limits for each individual measurement, by insertion of diode(s) or diode and resistor on programming boards.

iv) Built-in interface facilities, namely:-

Power supplies for test unit and ancillary equipment,

High-input-impedance unity-gain amplifiers,

x 10 amplifiers,

Differential amplifiers,

A.C./D.C. converter,

Programmable d.c. stimulus generator, 0 to 10V,

Programmable a.c. stimulus generator 20Hz to 20kHz, with sine-wave, square-wave and triangular-wave outputs,

Ramp generator for use as a varying-d.c. stimulus or, with the a.c. generator, to provide a sweep frequency a.c. output,

Monostable to provide programmable time intervals,

Sample-and-Hold to measure varying signals at defined times,

Relays for switching internal or external equipment.

Access to the interface facilities is obtained by wire link connections on the programming boards.

v) Sixty control lines (one for each test), each energised automatically as the test is called, to call up the required internal facilities or external test apparatus either directly or via the built-in relays.

vi) Control of the delay period between the application of stimuli to the test unit and the commencement of measurement, by inserting diode and resistor on programming boards.

vii) Adjustment of test unit controls during measurement by use of Semi-Auto or Manual operating mode.

viii) Location of intermittent faults in test unit by use of Recycle mode.

ix) Purpose-built circuits to carry out additional functions can be mounted on test panel.

x) Signals can be fed to or from external test equipment via built-in interconnection lines and a socket at the rear of the A60.

xi) Direct access via front-panel co-axial socket to d.c. measuring circuit.

xii) Output of test data via rear-panel socket for connection to external printer.

The interface devices, e.g. power supplies, amplifiers, etc., which can be interposed between the A60 and the unit under test, are fully described in Section 3 (see Contents List).

The basic measuring functions, e.g. programming for the magnitude and polarity of the test voltage, selection of tolerance limits etc., are also detailed in the Contents List and are fully described in Section 4.

This manual describes the basic operating principle and facilities of the A60 and gives detailed programming instructions. The latter are presented in such a manner that only the most basic circuit theory is necessary to bring the instrument into full operational service.

A separate publication, the Maintenance Manual, is available to order. This gives a full circuit description, circuit diagrams, and component list, and describes setting-up and checking procedures.

The A60 should be connected to the mains supply by a 3-pin plug wired:-

Yellow/Green	to Ground,
Blue	to Neutral,
Brown	to Live.

Separate models are supplied for 50Hz (200-250V) and for 60Hz (100-130V) and they are not interchangeable.

2.0 FUNCTIONAL DESCRIPTION

2.1 Measuring Circuit

The d.c. measuring circuit of the A60 is shown in simplified form in Fig. 2.

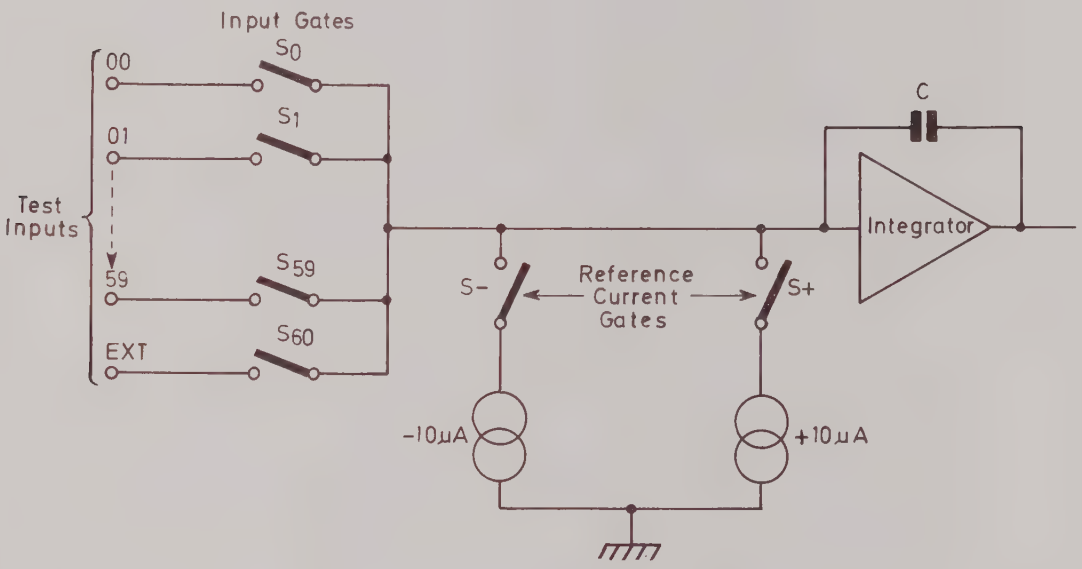


FIG. 2 SIMPLIFIED DIAGRAM OF D.C. MEASURING CIRCUIT

For measurements of positive or negative direct voltages, the circuit points under test are connected to the A60 test inputs through scaling resistors of such value as to produce an input current of 10μA when the test voltage is at its specified nominal value. For measuring alternating voltages, a unity-gain a.c.-to-d.c. converter is interposed between the test item and the scaling resistor.

As the A60 proceeds through the sequence of tests, the FET gates S_o, S_1-------S_{59} are closed in turn, feeding the test input currents successively into the integrator.

A 10μA reference current of polarity opposite to that derived from the test item is also injected into the integrator. Thus, if the test voltage is at its correct nominal value, the net input

current is zero. If the test voltage is not at its nominal value, a positive or negative error current, which is the measure of the error in the test voltage, flows into the integrator.

For 'Balance' measurements, i.e. test voltages that are nominally zero, no reference current is injected and only the current derived from the test item flows into the integrator.

The output voltage of the integrator is proportional to the product of the input current and the time for which this current flows. The measurement of the net input current is made using the dual-slope integrating technique illustrated in Fig. 3.

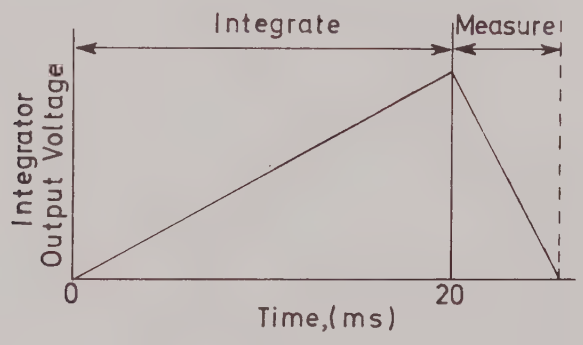


FIG. 3 OPERATION OF DUAL-SLOPE INTEGRATOR

The net input current is applied to the integrator for a period of approximately 20ms, as measured by an internal timing clock. At the end of this 'Integrate' period, the test and reference current gates open and the integrator output voltage polarity is sensed.

The 'Measure' period then follows, during which a reference current of 10μA, and of polarity opposite to that of the net input current during the 'Integrate' period, is injected and the integrator output voltage returns linearly to zero.

Since the duration of the 'Integrate' period is fixed, the output voltage at the end of that time is determined only by the error current. Since the reverse-polarity input current in the 'Measure' period is fixed at 10μA, the time taken for the integrator output voltage to return to zero is determined only by the magnitude of that voltage at the end of the 'Integrate' period. Thus the duration of the 'Measure' period is a direct indication of the magnitude of the error current, i.e. of the deviation of the test voltage from its nominal value.

This duration is measured by the timing clock, is displayed, suitably scaled, on the '%Deviation' digital meter, and also controls the 'Fault' indicator displays.

2.2 Switching and Control

The A60 carries out the programmed series of tests either automatically or step-by-step under manual control. As each test is called, the appropriate test-select line on the program board is switched from approximately -15V to approximately +15V and the corresponding input pin on the input/output board is connected to the measuring circuit input.

The voltage change on the test-select line is used to program the various measurement functions and to control the internal relays, or external FET switches, for calling up the built-in facilities or external apparatus as required.

2.3 Modes of Operation

Progression from one test to the next, as selected by the front panel push-buttons, can be:-

a) Manual - by pressing the 'Step' button once for each advancement. In this mode the A60 measures repeatedly at intervals of approximately 80ms at each test point and the % deviation display is continuously updated.

b) Auto - electronic scanning proceeds once through the program, stopping at any test point at which the voltage is outside the programmed tolerance limits. Scanning is resumed on pressing the 'Step' button.

c) Semi-Auto - as for (b) except that scanning is resumed automatically when the voltage at a 'faulty' test point is brought within the programmed limits. While the scanning is stopped, the % deviation display is continuously updated.

d) Recycle - as for (b) but the entire scanning sequence is repeated continuously until a fault is found. (See Section 4.3.12).

The digital meter indicates the result of each test in turn as the A60 proceeds through the sequence, regardless of the mode. The mode selected is determined by the nature of the test item.

Manual operation gives the user continuously updated readings of the percentage by which the measured voltage deviates from its nominal value.

Semi-Auto is appropriate when the test procedure requires the adjustment of a number of preset controls.

Auto is generally the most useful mode, suiting the majority of test requirements.

Recycle is valuable for the location of intermittent faults and for soak testing.

In addition to selecting the desired overall mode by the panel push-buttons, certain changes of mode or timing can be selected by program for individual tests during the cycle (see Section 4.3.12).

2.4 Fault Indication

Instruments with Serial Nos. 102 and above

i) In 'Auto' mode, when a test result is outside the programmed tolerance limits, the 'Fault Found' and either the 'Fault +ve High' or 'Fault -ve Low' displays

illuminate and the test sequence is halted. When the 'Step' button is pressed, whether the fault has been remedied or not, the test sequence resumes and the 'Fault High' or 'Fault Low' display extinguishes but the 'Fault Found' display remains lit and the 'Test Complete O.K.' signal is not given at the end of the sequence.

The 'Fault Found' display, once lit, extinguishes only when the 'Start/Reset' button is pressed. The 'Test Complete O.K.' display lights only at the end of a complete test sequence in which no fault has been found.

ii) In 'Recycle', the operation of the fault indicators is as in 'Auto', except that the 'Fault Found' display extinguishes automatically as the A60 makes its transition from the end of one sequence to the beginning of the next. Also, since the instrument does not stop at the end of a test sequence, the 'Test Complete O.K.' display never illuminates.

iii) In 'Manual', when a fault is found, the sequence stops, the 'Fault High' or 'Fault Low' display lights, but initially the 'Fault Found' display does not. If the faulty test result is brought within the programmed limits and then the 'Step' button is pressed, the 'Fault Found' display does not light and 'Test Complete O.K.' display lights at the end of the sequence.

If, on the other hand, the 'Step' button is pressed with the faulty test result not corrected, the 'Fault Found' display illuminates and remains on and the 'Test Complete O.K.' signal does not light at the end of the sequence.

iv) In 'Semi-Auto' the fault indicators operate as in 'Manual' except that, if the faulty test result is brought within limits, the sequence resumes automatically without the 'Step' button being pressed.

Instruments with Serial Nos. up to 101

In all modes, the fault indicators operate as described above in (i) for the 'Auto' mode.

Note: Early production models of the A60 can be altered (as a factory modification) to give the type of fault indication embodied in later models if required.

3.0 INTERFACE FACILITIES

Access to the facilities described in Sections 3.1 to 3.9 is provided on the Input/Output board.

3.1 D.C. Supplies

Power for the test item is provided from two stabilised, floating supplies in the A60.

These can be used independently, in series, or in parallel. Each supply, A and B on the Input-Output Board (see Fig. 4), is current-limited at approximately 0.5A and can be programmed to provide any voltage between 5V and 18V, determined by the value of the supply resistor according to the formula

$$R = \frac{5.28}{V - 1.6} \quad (R \text{ in } k\Omega,\ V \text{ in volts})$$

The curve of this formula is given in Fig. 5.

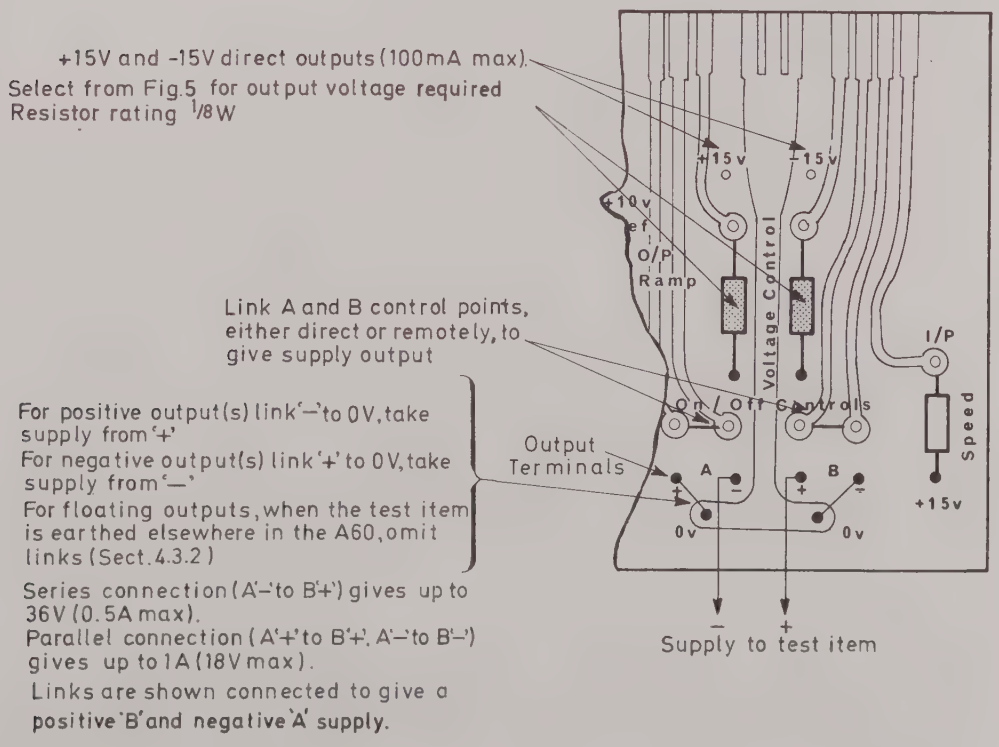

+15V and -15V direct outputs (100mA max).
Select from Fig.5 for output voltage required
Resistor rating 1/8W
Link A and B control points, either direct or remotely, to give supply output
For positive output(s) link '—' to 0V, take supply from '+'
For negative output(s) link '+' to 0V, take supply from '—'
For floating outputs, when the test item is earthed elsewhere in the A60, omit links (Sect. 4.3.2)
Series connection (A'–' to B'+') gives up to 36V (0.5A max).
Parallel connection (A'+' to B'+', A'–' to B'–') gives up to 1A (18V max).
Links are shown connected to give a positive 'B' and negative 'A' supply.
+15v
–15v
+10v ref
O/P Ramp
Voltage Control
On / Off Controls
I/P
Speed
Output Terminals
A
B
0v
0v
+15v
Supply to test item

FIG. 4 TYPICAL POWER-SUPPLY LINK WIRING

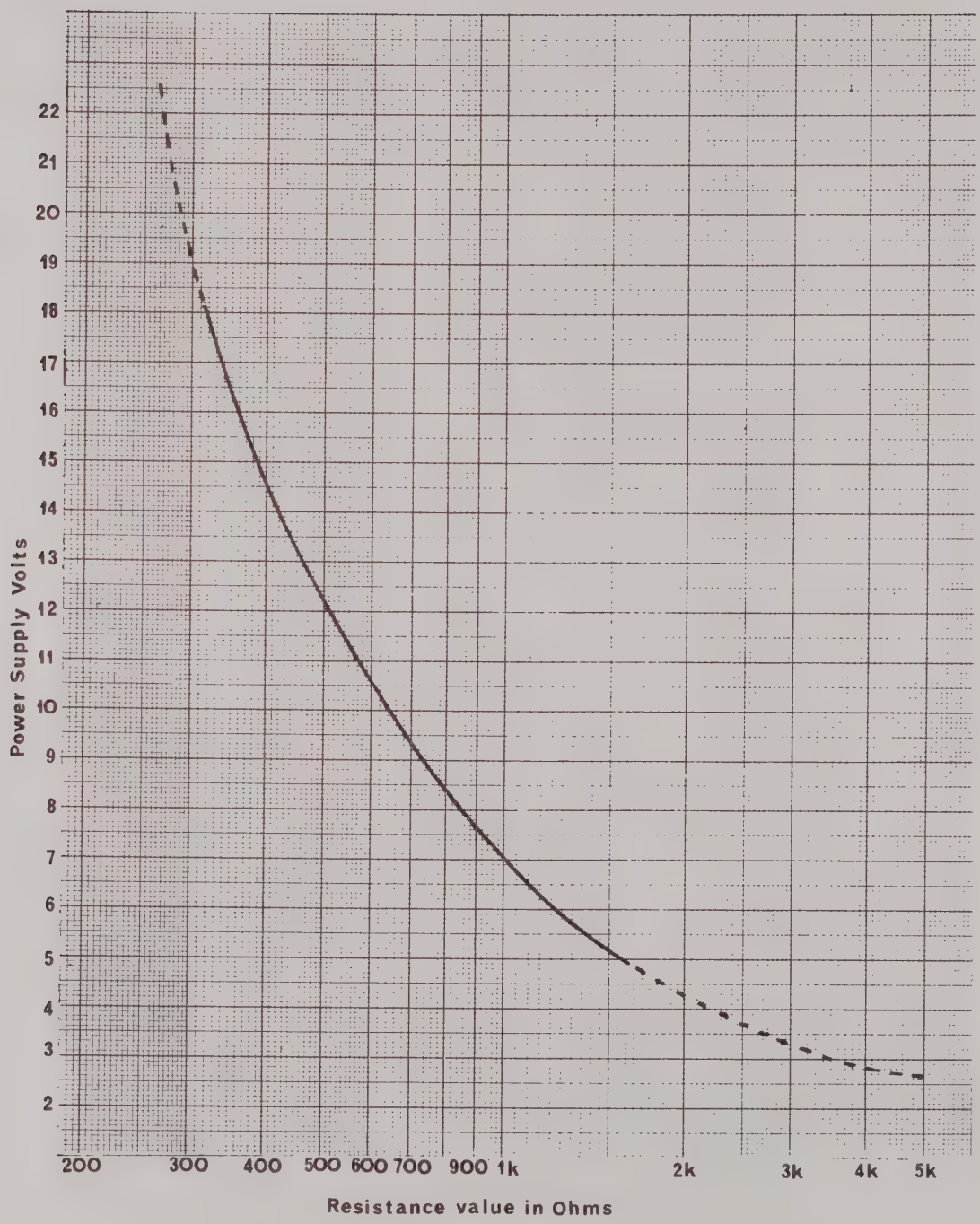


FIG. 5 POWER-SUPPLY RESISTOR SELECTION CURVE

The supply voltages are present only when the corresponding two Control points are connected together, i.e., "A" Control points for "A" output, "B" Control points for "B" output, see Fig. 4.

These connections can be made by relays as part of the program, by microswitches associated with the fitting of the test item on the jig, or where no control is required, a permanent link can be soldered.

A +15V and -15V direct output is available on the board. These supplies are stabilised and will supply up to 100mA max. They are primarily intended for powering ancillary equipment but can be used to augment the supply to the unit under test where the maximum voltage available from the A and B supplies is inadequate, provided that the maximum current demand does not exceed 100mA and that the common-point connection of the ±15V supplies to the 0V line is acceptable.

Note: The +15V and -15V direct supplies are used also within the A60. Care is therefore necessary that externally-connected equipment does not feed transients, e.g., from switching surges, back into the instrument and that the external equipment is not itself disturbed by traces of internal switching waveforms fed out on the ± 15V supplies.

If the built-in power supplies of the A60 are inadequate for the unit under test it is quite feasible to use an external power supply. Precautions against induced hum may be necessary when choosing the correct 0V return point for the 'Earthy' side of such an external supply. (Section 4.3.2.).

3.2 Relays

The contacts of ten high-grade, diaphragm, single-pole change-over relays (ITT Type 111 AAM) are accessible on the input/output board. These can be used for any d.c. switching purpose and, with certain restrictions, for a.c. switching.

The manufacturers specification for these relays includes:-

Maximum ratings of the contacts:

Power: 30W, A.C. or D.C., with resistive load.

Voltage: 100V, A.C. or D.C.

Current: 500mA, A.C. or D.C.

Life Expectancy: 10^9 operations on no load ('dry' switching), decreasing to 10^6 operations on a 60V, 500mA d.c. load.

Access to the relay control inputs is provided on the program board (see Section 4.3.9).

A relay operates approximately 17ms after the control input is applied and returns with a much shorter delay, of the order of 1ms, when the input is removed.

Thus, if the control input is applied to relay A at the same instant as it is removed from relay B, the change-over of B will be completed before that of A commences.

Also, if one relay is called on two or more immediately successive tests, it will remain operated without returning at the test-number changeover. The test-select line changeover time is much shorter than the relay return delay.

The usual precautions should be observed when switching inductive, capacitive, or filament lamp loads. Inductive loads should be clamped with diodes. Capacitor charge and discharge currents, and the initial surge current of filament lamps, should be limited with resistors to within the specified 500mA. It should be borne in mind that the initial current in a filament lamp can exceed the nominal running current by a factor of ten or more.

A.C. applications of the relays are limited by the capacitance, both across the contacts and from the contacts to earth, of the associated wiring. This subject is dealt with in detail in Section 4.3.1.

3.3 Amplifiers

These consist of:-

- 4 - low-input-resistance (40kΩ), unity-gain, differential amplifiers,
- 8 - high-input-resistance (>10MΩ), unity-gain, non-inverting amplifiers,
- 1 - very-high-input-resistance (>1000MΩ) unity-gain non-inverting amplifier, and
- 2 - high-input-resistance (10MΩ) A.C. only, X10, amplifiers.

The connections to these are shown in Fig. 6. The frequency ranges covered are given in the specification. Normally, each differential amplifier will be preceded by two high-input-resistance amplifiers, as shown in Fig. 7. In this configuration, non-inverting inputs are A, C, E and G; inverting inputs are B, D, F and H.

Note that, although this circuit configuration is the normal method of use, the necessary connections between the X1 amplifiers and the differential amplifiers are not provided on the board and have to be made by wire links as shown in Fig. 6.

Note that for a.c. inputs, the differential system is limited to a slew rate corresponding to an input of 1.5V peak at 20kHz, so it may be necessary to attenuate the differential input voltage.

The individual high-input-resistance buffer amplifiers that normally form part of the differential amplifier system can be used separately, e.g. for impedance transforming. It is not recommended that a differential amplifier is used without its two input buffers since its gain would then depend upon the source impedance from which it was fed and its common-mode rejection could be impaired.

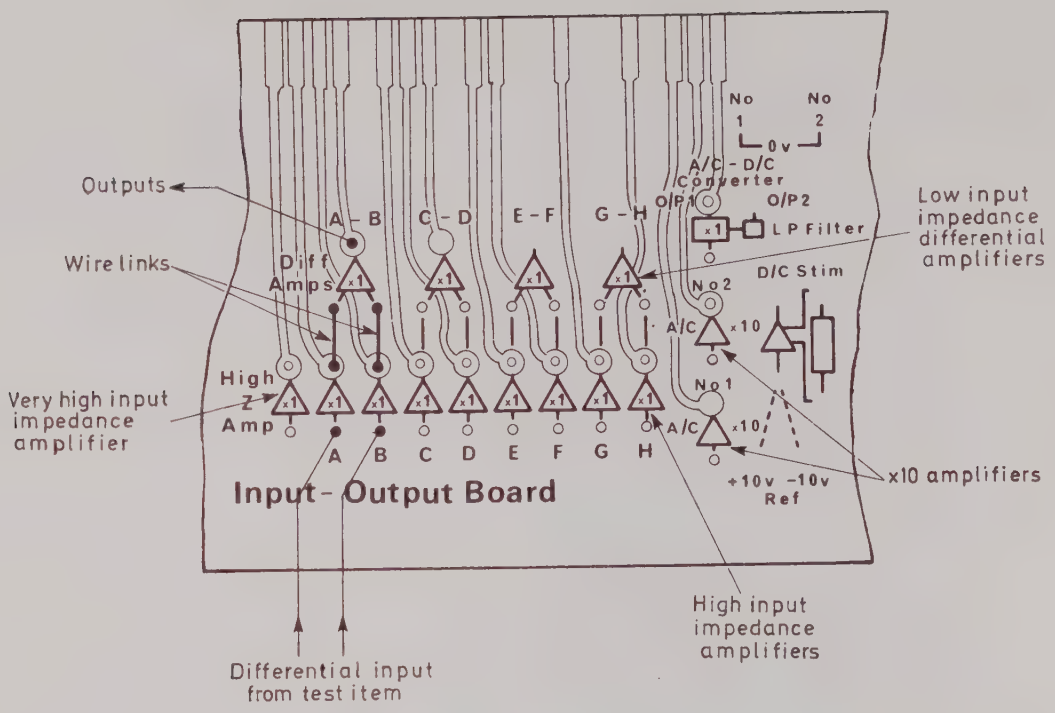


FIG. 6 TYPICAL DIFFERENTIAL AMPLIFIER CONNECTIONS

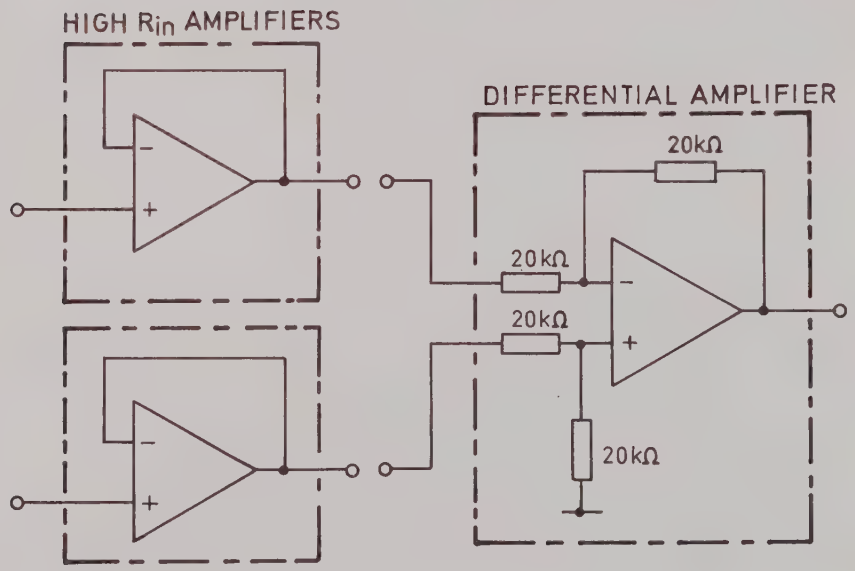


FIG. 7 SIMPLIFIED CIRCUIT DIAGRAM OF DIFFERENTIAL AMPLIFIER ASSEMBLY

The very-high-input-resistance, non-inverting, unity-gain a.c./d.c. amplifier has an input resistance of 10^9 ohms and can be used where the test source is very sensitive to loading. It is intended for use in d.c. and low-frequency a.c. measurements only, since its slew rate limitation corresponds to an input of 1.5V peak at 2kHz. When used for d.c. measurement, the amplifier input is wired directly to the appropriate point on the test item, and the output to the d.c. scaling resistor.

The 'X10' amplifiers are a.c. coupled, non-inverting, and provide 20dB voltage gain over the frequency range 20Hz to 20kHz. The input impedance is nominally 10MΩ in parallel with typically 350pF. They can be used in cascade to provide 40dB voltage gain (see also Section 3.4).

3.4 A.C. - D.C. Converter

The converter is mean-reading and the conversion factor is unity for a sinusoidal input, i.e., 1V r.m.s. sine-wave input gives 1V d.c. output.

For measurements on non-sinusoidal waveforms, the conversion factor applicable can be ascertained by feeding a known amplitude of the a.c. signal into the converter and measuring the resulting d.c. output.

If the signal from the test item is between 1V and 10V peak, it can be wired directly to the input of the converter. If it is between 0.1V and 1V peak, one of the X10 amplifiers, and if below 0.1V peak the two X10 amplifiers in cascade, should be interposed between the test item and the converter input. For inputs greater than 10V peak, a voltage divider should be inserted to attenuate the signal to a usable level.

When more than one a.c. measurement is to be made, the necessary switching at the input to the converter, and of the amplifiers if they are required, should be carried out with FET switches. (Section 4.3.1).

For a.c. measurements in the frequency range 200Hz to 20kHz, the '0P1' output of the converter should be used. At frequencies below 200Hz, the 0P1 output contains an a.c. ripple component that could impair the accuracy of measurement. For measurements between 20Hz and 200Hz therefore, the 0P2 output, which incorporates a low-pass filter, should be used. This output has a long time-constant and takes more than a second to settle after the input has been applied. To allow for this, at least two seconds must be allowed to elapse between the application of the a.c. test voltage to the converter and the commencement of the measurement.

This can be done by programming a two-second delay for the test (Section 4.3.12). Alternatively, it might be arranged that the test in question is preceded by a sufficiently long sequence of d.c. measurements and the a.c. input connected to the converter either permanently, if it is the only a.c. test, or through a 'normally closed' FET switch if other a.c. measurements are programmed.

Another possible source of error in a.c. measurements is the transient disturbance to the measurement system caused by switching to a test point carrying a fixed d.c. potential in addition to the a.c. voltage that is to be measured. The need to program a delay in such cases can be avoided by wiring the test point permanently to a series capacitor followed by a shunt resistor to the '0V' line. The input to the measuring system (amplifier, converter, or FET switch) is taken from the junction of the resistor and capacitor, as shown in Fig. 8.

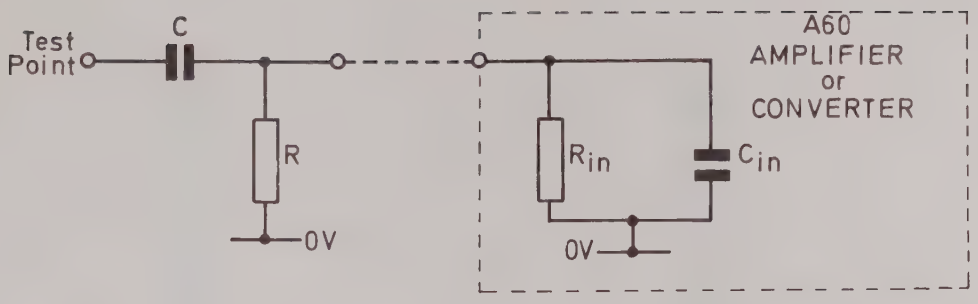


FIG. 8 METHOD OF CONNECTION FOR A.C. MEASUREMENT AT TEST POINT CARRYING D.C. POTENTIAL

The value of R should be chosen bearing in mind the loading imposed on the test point. C forms an a.c. potential divider with the impedance presented by R, R_{in} and C_{in} in parallel, and should either be of sufficiently high capacitance to be negligible or its impedance should be allowed for. The time constant CR should be short enough for the capacitor C to charge substantially to the direct voltage at the test point before the test is called.

The smallest signal that can be measured accurately with two X10 amplifiers in cascade is about 5mV r.m.s. Smaller signals can be measured with reduced accuracy but care must be taken to avoid interference problems. The wiring from the amplifier input pins on the Input/Output board may pick up mains hum and also switching-spike interference from the sine-wave oscillator when the latter is operating.

The A.C. Source (Section 3.6) can be made inoperative, if not required for that particular test, by short-circuiting the Frequency Control Capacitor pins by means of a FET switch (Fig. 23 and Section 7.6).

3.5 Ramp Generator

The ramp is called up by connecting a programming diode from the test-select line concerned to the 'Ramp' function control

track on the Program board.

The output is positive-going and starts from 0V when the ramp test is selected. The nominal ramp sweep is 0 to 10V. When the output reaches a set threshold voltage (about 11V to 12V), the machine steps on to the next test (if the Auto mode is selected) and the ramp output drops back to 0V. In Manual, the ramp output reaches a saturation level of about 14V, to drop back to 0V after stepping on to the next test manually.

Note that the ramp must not be called on two or more immediately successive tests. After use, it requires one test period to recover.

The ramp output load resistance should not be less than 10kΩ; a lower value may prevent the output reaching the threshold voltage.

The time taken for the ramp to reach 10V is directly proportional to the value of the input resistor and inversely proportional to the input voltage. For ramp durations of 10 seconds or less, the circuit of Fig. 9(a) should be used. R_{in} = 4.7MΩ gives a duration of approximately 10 seconds. For durations longer than 10 seconds, use the circuit of Fig. 9(b) with R_{in} = 4.7MΩ, R_1 = 10kΩ and R_2 of the appropriate value to give the input voltage required. (R_2 = 1.1kΩ gives a duration of approximately 100 seconds).

A series input resistor of 4.7kΩ is built into the ramp generator (as shown in Fig. 10). If ramp durations less than about 100 milliseconds are required, this should be allowed for by making the appropriate reduction in the value of the external input resistor R_{in}.

The ramp as described above is linear. An exponential ramp can be generated using the arrangement shown in Fig. 10 which incorporates the operational amplifier from the d.c. stimulus circuit (see Section 3.8).

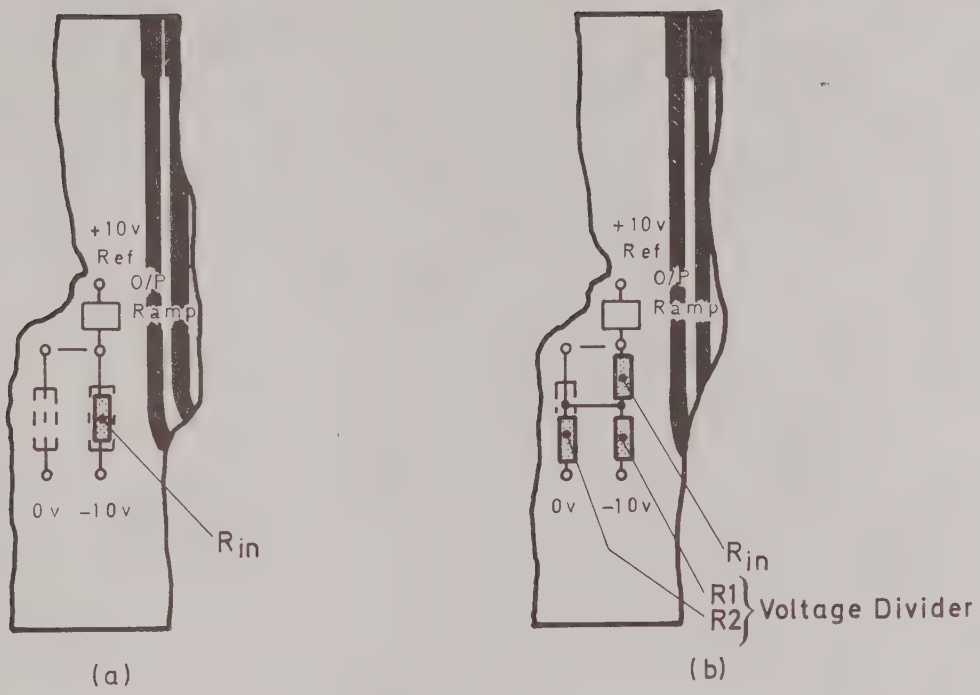


FIG. 9 RAMP GENERATOR CONNECTIONS

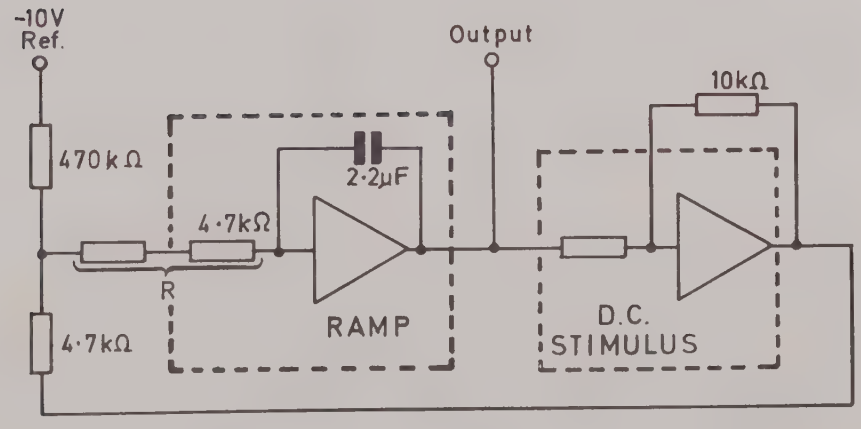


FIG. 10 EXPONENTIAL RAMP GENERATOR

The principle of operation is as follows: at start the ramp output is 0V. As the output voltage rises, it is inverted in the D.C. Stimulus op. amp., programmed for unity gain, and fed back to the ramp input. Consequently the output rate of change increases as the output voltage rises.

The ramp duration is

$$T = 10R \quad (T \text{ in seconds, } R \text{ in megohms})$$

and this formula is valid for $R \geq 50k\Omega$.

3.6 A.C. Source

The oscillator covers the range up to 20kHz and the frequency is controlled by a resistor, a capacitor and a DC voltage. The formula is:

$$f = \frac{0.1\,RV}{1 + C} \quad \begin{matrix}(f \text{ in kHz, } R \text{ in } k\Omega, \text{ V in volts,} \\ C \text{ in nanofarads})\end{matrix}$$

For V = 10V, C = 0, the frequency in kHz equals the resistance in kΩ.

For maximum frequency accuracy and minimum distortion it is recommended that the resistance R is between 2kΩ and 20kΩ and the voltage V = 10V. This drive voltage is obtained by linking "I/P" to "+ 10V ref" (Fig. 11). The capacitor will then be used to obtain frequencies below 2kHz.

Examples: for 10kHz R = 10kΩ, C = 0, V = 10V
1kHz R = 10kΩ, C = 9nF, V = 10V
20 Hz R = 20kΩ, C = 999nF, V = 10V

When a series of fixed frequencies is required, the built-in relays can be used to switch the programming resistors. Use of the relays to switch the capacitors could result in parasitic oscillation and it is therefore recommended that the FET switch circuit of Fig. 12 is used for this purpose.

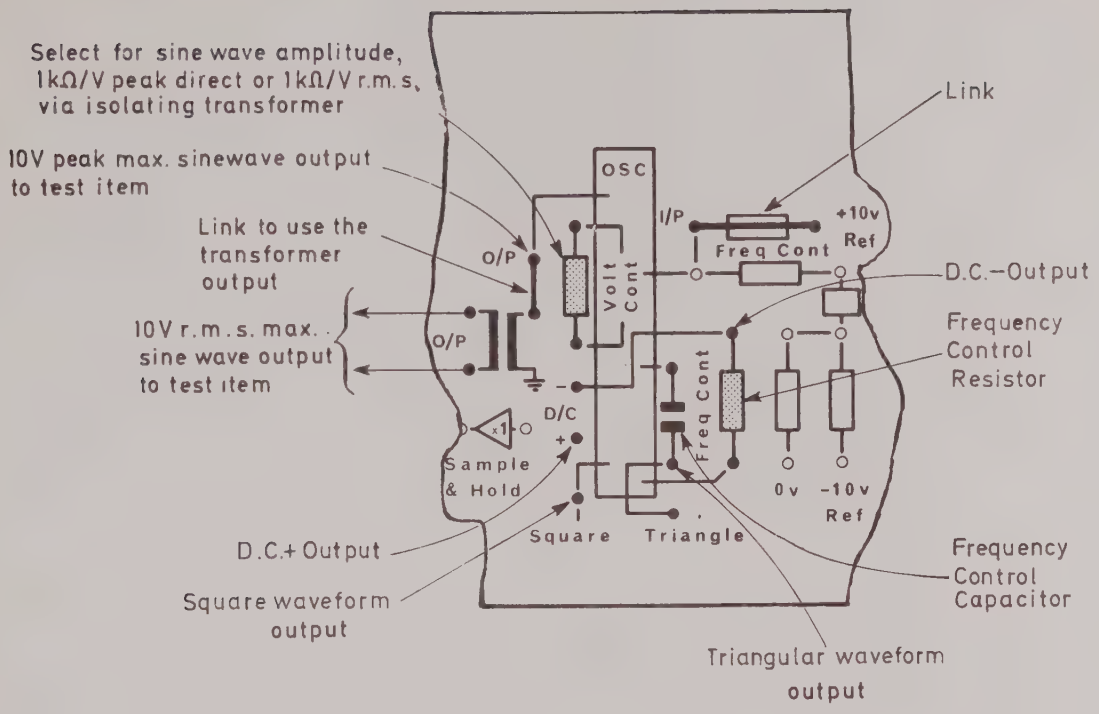


FIG. 11 A.C. SOURCE CONNECTIONS

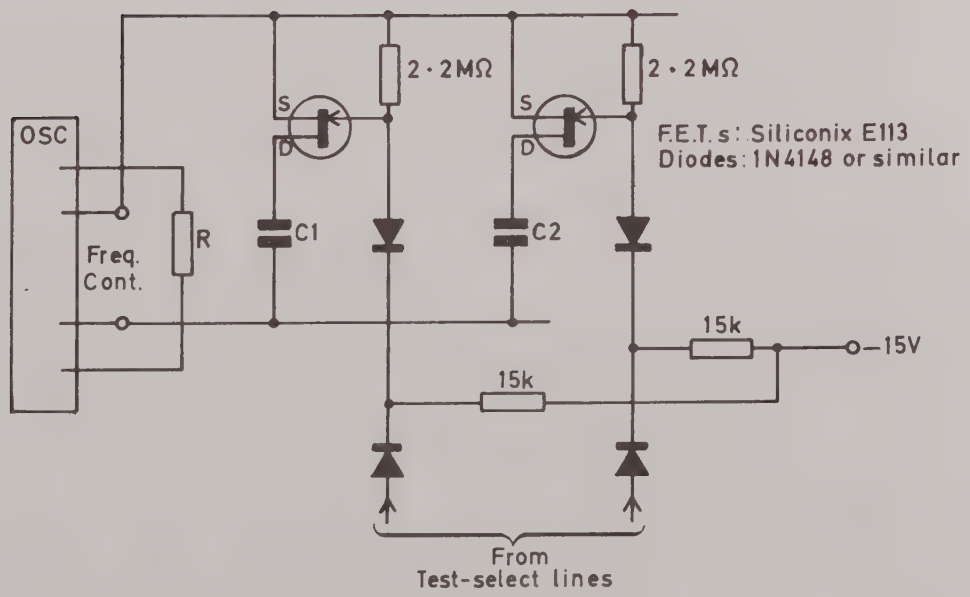


FIG. 12 FET SWITCH CIRCUIT FOR SWITCHING A.C. SOURCE FREQUENCY-CONTROL CAPACITORS

The voltage control is designed for use when the oscillator is coupled to the ramp generator, see Section 3.7.

Two d.c. outputs, each proportional to the instantaneous value of the oscillator frequency in both the fixed-frequency and sweep modes, are available at the points marked 'D.C. + Output' and 'D.C. - Output' in Fig. 11.

These two voltages are numerically equal, though of opposite polarity, and are related to the oscillator frequency by the formula:

$$V = \pm\frac{1}{2} f\ (C+1)$$

where V = output voltage in volts

f = oscillator frequency in kHz

C = capacitance of frequency control capacitor in nanofarads.

The source impedances of both voltage outputs are low, ($<1\Omega$) but the resistance of any external load must not be less than $100k\Omega$.

The sine-wave output from the oscillator is obtained from the point labelled O/P on the input/output board (Fig. 11). The output level is controlled by a resistor and the formula is:

V out (peak volts) = R (in kilohms)

Thus a $10k\Omega$ resistor will produce an output of 10V peak, i.e. 7.07V rms, which is the maximum output that can be obtained before the onset of clipping.

For maximum accuracy of output level, the programming resistor should not be of lower value than 100Ω. To obtain output voltages below 100mV peak, a voltage divider should be used.

If a floating output is required, the isolating transformer may be used. It is a step-up transformer, turns ratio $1:\sqrt{2}$ and so the voltage range is extended up to 10V r.m.s. Using the transformer degrades the level accuracy; an additional tolerance of 5% can be expected.

To use the isolating transformer, link the primary to the oscillator direct output (Fig. 11).

The minimum permissible values of load resistance are: 2kΩ for the oscillator output, 10kΩ for the transformer output.

Square and Triangular-Wave Outputs

Square and triangular-waveform outputs are also available. The triangular-wave is in phase with the sine-wave and its amplitude is ± 10V peak (Fig. 13).

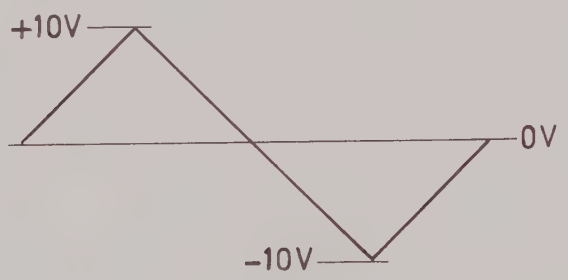


FIG. 13 TRIANGULAR OUTPUT WAVEFORM

The source impedance is low (a few ohms), but the load resistance should not be less than 10kΩ.

The square wave leads the sine-wave by 90° and the output e.m.f. is negative-going from 0V to approximately -15V from a 4.7kΩ source resistance. It requires an external load resistor not greater than 10kΩ to obtain reasonably fast edges. With a 10kΩ load returned to the 0V line, the output swing is approximately 0V to -10V.

Alternatively the load resistor can be returned to the +15V line to obtain a ±5V swing about approximately zero.

The square-wave output can be safely loaded with any resistance down to short-circuit, hence any value of output voltage up to the maximum stated above can be obtained by choosing the appropriate value of load resistor.

3.7 Sweep Oscillator

This consists of the a.c. source driven from the ramp generator and a number of modes of operation are possible, viz,

i) Linear sweep from below 20Hz to at least 20kHz.

ii) Linear sweep starting above 20Hz and finishing at 20kHz.

iii) Linear sweep over any part of the range 20Hz to 20kHz.

iv) Exponential sweep over any of the above ranges.

To obtain (i), the connections are as shown in Fig. 14(a). The oscillator input is linked not to the +10V ref. but to the ramp output, the frequency control resistor is 20kΩ, and no frequency control capacitor is used.

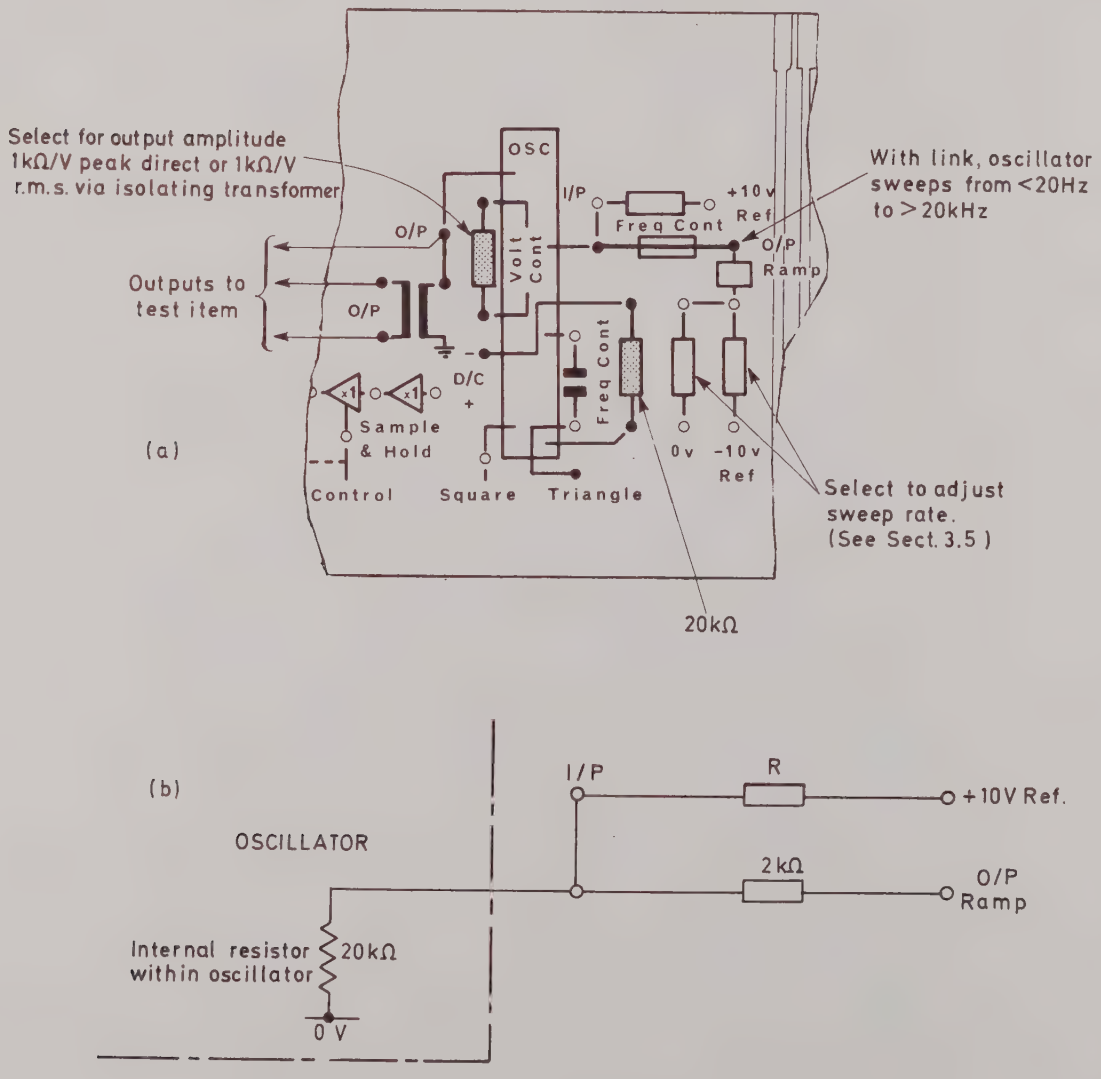


FIG. 14 SWEEP OSCILLATOR CONNECTIONS

For (ii), the connections are as shown in Fig. 14(b). At the start of the sweep, when the ramp output is zero, the voltage applied to the oscillator input is:-

$$10 \frac{1.82}{R + 1.82} \text{ V.}$$ (R in kΩ; 1.82kΩ is the parallel combination of 2kΩ and 20kΩ)

The starting frequency in kHz is therefore:-

$$f = 20 \frac{1.82}{R + 1.82}$$

For a given starting frequency f (in kHz), the resistor value required is:

$$R = \frac{36.4}{f} - 1.82\text{k}\Omega$$

The final frequency will remain 20kHz as the maximum ramp output is at least 11V.

For (iii), the programming procedure is similar to (ii) and the circuit is identical with Fig. 14(b), apart from the fact that a frequency control capacitor is used. To cover a frequency range f_1 to f_2 ($f_1 < f_2 < 20$kHz), first calculate the factor $P = \frac{20}{f_2}$, then evaluate R from the formula $R = \frac{36.4}{Pf_1}$ kΩ (f_1 and f_2 are in kHz).* Finally, calculate the value of the frequency control capacitor C = P-1 nF.

For (iv), any of the above arrangements can be used in conjunction with the exponential ramp generator described in Section 3.5

---

* Since the minimum permissible value of external load resistor for the ramp generator is 10kΩ (Section 3.5), the minimum value for R in Fig. 14(b) is 13.33kΩ. This sets limits to the maximum value of starting frequency and minimum value of end frequency in restricted-range sweeps, unless a unity-gain amplifier is used as an impedance converter.

3.8 D.C. Stimulus

The D.C. Stimulus operational amplifier can be programmed as shown in Fig. 15 to provide a positive or negative voltage basically in the range 0.1V to 10V but lower voltages can be obtained with reduced accuracy. The output voltage is determined by the programming resistor according to the formula

$$V = R$$

where V is in volts and R in kilohms.

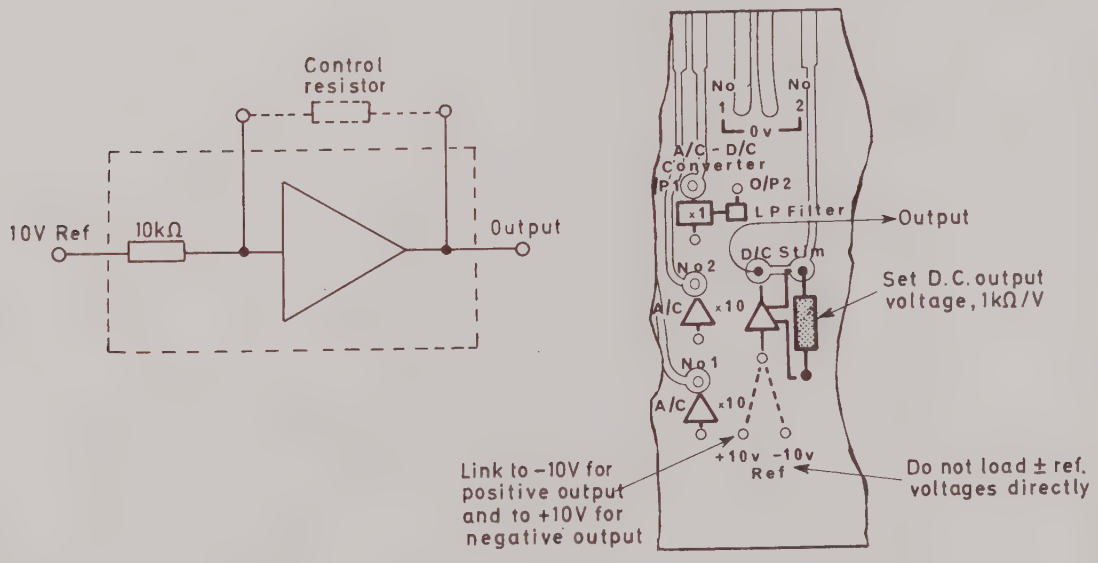


FIG. 15 D.C. STIMULUS CONNECTIONS

The D.C. stimulus can be used as an inverting operational amplifier, bearing in mind that it has a fixed input resistor of 10kΩ permanently connected.

3.9 Monostable and Sample-and-Hold

The monostable is used to provide a defined time interval. The output is a positive pulse and it is triggered by a positive step (see Fig. 16). The duration, T, of the output pulse is determined by the values of timing capacitor and resistor, which are selected according to the curve of Fig. 17.

For pulse durations above 100μs, the timing resistor is 100kΩ to give the maximum stability. Below 100μs, the value is reduced to 10kΩ in order that the stray wiring capacitance across the timing capacitor terminals (approximately 100pF) shall not be too high a proportion of the total capacitance in the circuit.

Fig. 17 represents average values, individual models may show some variation from these. Where the pulse duration is critical, it should be checked and any necessary correction to the timing capacitor made.

If it is more convenient to trip the monostable with a negative (+15V to -15V) step, the inverter may be used. The inverter may alternatively be used to invert the output pulse to a negative (+15V to -15V) one, for example, if the monostable is required to drive the sample-and-hold.

The sample-and-hold circuit enables the value of a signal to be measured at a defined time. This time is determined by an input on the control line. When the control line is at -15V, the S & H output follows the input (subject to slew rate limiting of 10V/ms) and, after the control input changes to +15V, the S & H holds the level which was present at the moment of the control input change. The circuit can accept an input voltage range of ±10V and the output drift in the hold mode is less than 5mV/s.

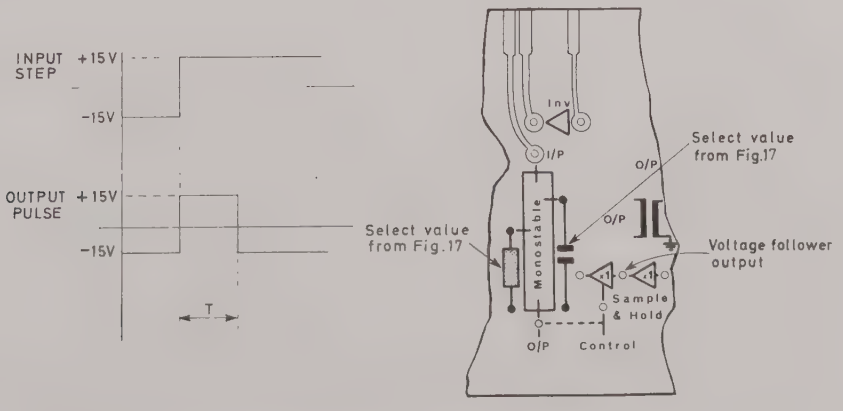


FIG. 16 MONOSTABLE: TRIGGERING AND OUTPUT WAVEFORMS AND CONNECTIONS

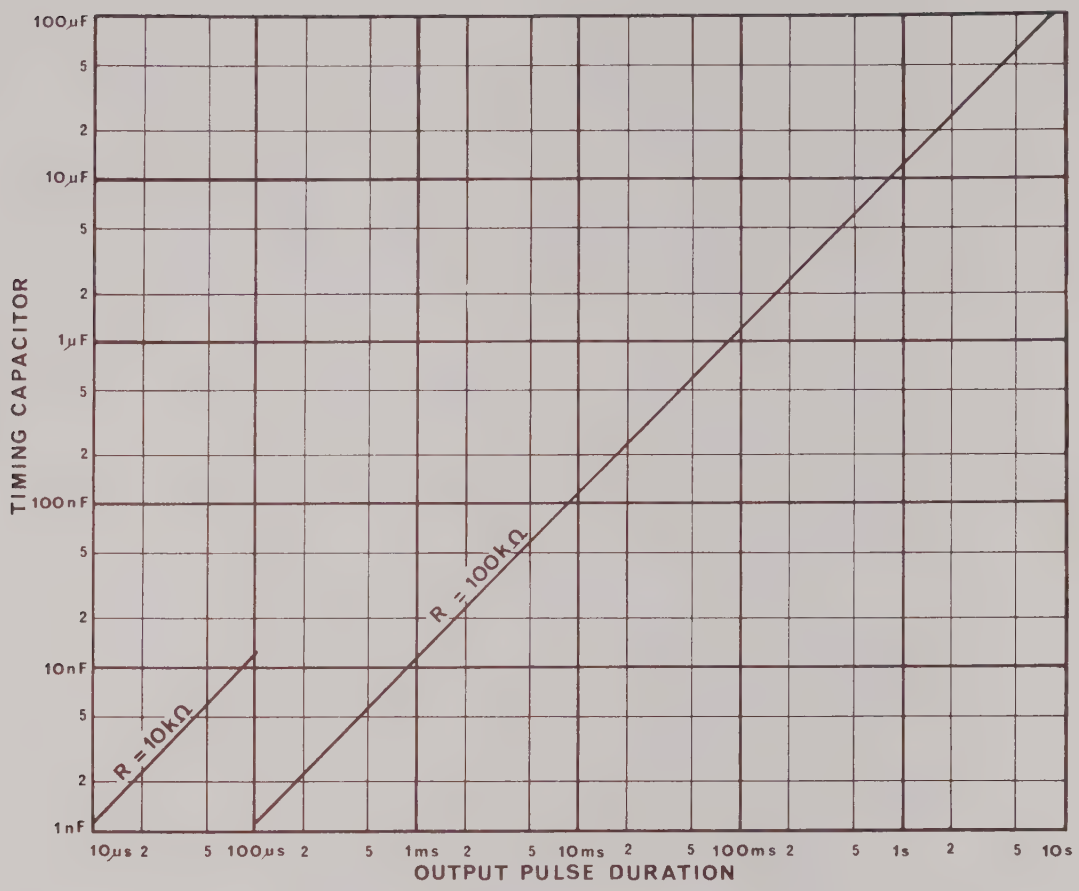


FIG. 17 MONOSTABLE TIMING CAPACITOR SELECTION CURVE

A typical application is the measurement of a varying D.C. signal at a defined time after selection of a test. The test select line is wired to the input of the monostable, triggering it when the test is selected. The monostable is programmed for the desired time interval T and its output connected, through the inverter, to the sample-and-hold control input. The sampling of the S & H input D.C. voltage begins at the moment of the test selection and, after the programmed time interval, the signal value is held.

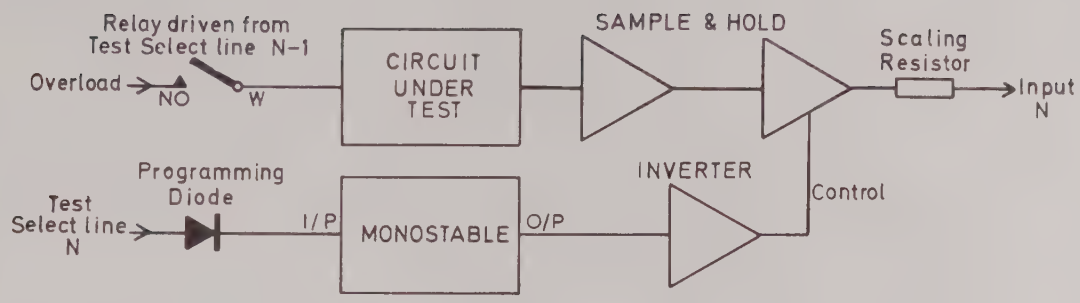


FIG. 18 TEST ARRANGEMENT USING MONOSTABLE AND SAMPLE-AND-HOLD

The A60 has to be programmed for a test delay exceeding the monostable period to avoid measuring during the sampling period (see Section 4.3.12, use of 'Slow' facility).

An example of a possible use of the monostable and sample-and-hold, to test the recovery of a circuit from overload, is given below.

Assume that a given point in the circuit of the test item is driven negative under input-overload and that test N is required to measure the voltage to which this test point recovers 120ms after the input is reduced to zero.

The test arrangement required is shown in the block schematic of Fig. 18, voltage and timing waveforms are shown in Fig. 19.

The program-board test-select line N is connected through a diode to the monostable input. The values of capacitor and resistor required to give a monostable output pulse duration of 120ms, shown in Fig. 17 as 1.3μF and 100kΩ, are connected as shown in Fig. 16.

The overload input is applied for the period of test N-1. This can conveniently be done by connecting the input to the test item through the normally-open contacts of one of the A60 relays driven from test-select line N-1.

In Fig. 19 the delay that occurs between the removal of the control voltage from the relay and the opening of the contacts has been ignored because it is short compared to 120ms.

A test delay of 300ms is programmed by connecting a diode from test-select line N to function control input 'Slow' and inserting a 160kΩ resistor (see Section 4.3.12 and Fig. 31) between the 'Speed' pins on the Input/Output board.

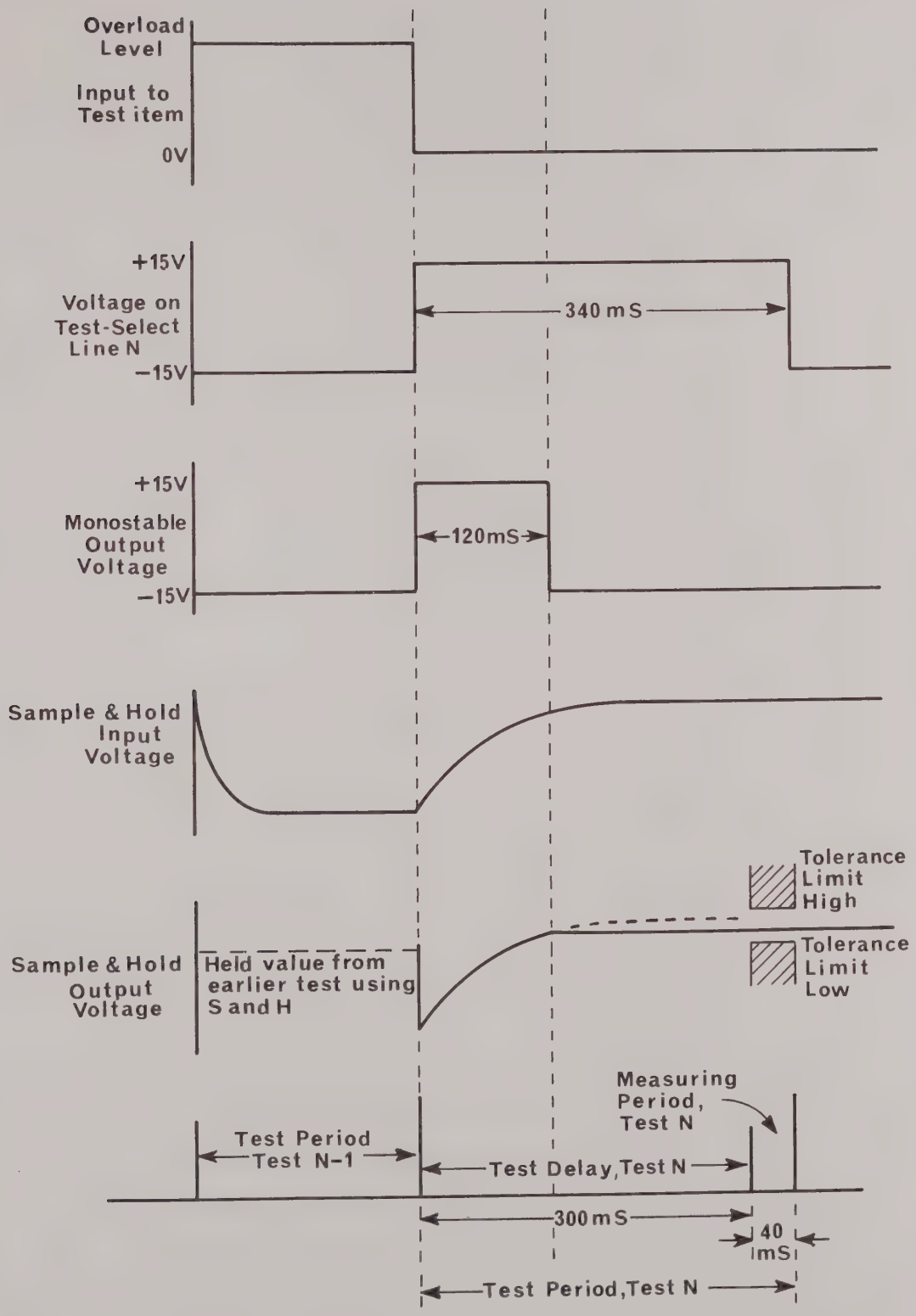


FIG. 19 WAVEFORMS IN MONOSTABLE AND SAMPLE-AND-HOLD TEST

4.0 PROGRAMMING PROCEDURE

4.1 Writing the Program

It is suggested that the following information should be listed on a program sheet similar to that shown in Fig. 20. (An example of a completed program sheet is shown in Fig. 39, Section 7.6)

a) The d.c. supplies required for the test item.

b) The tests to be made, in the order that will provide the maximum amount of diagnostic information, showing for each test:-

   i) The circuit points at which test outputs are to be measured and stimuli, if any, applied

   ii) The test output voltage expected (see paragraph (e) below)

   iii) The % variation permitted

   iv) The a.c. or d.c. stimulus required, and

   v) Any amplifiers, attenuators and special switching.

   The stimuli may be obtained either from the A60 or from ancillary equipment.

c) Calculate the value of a scaling resistor for each d.c. test point. These should be 100kΩ per volt measured.* For example, if the nominal voltage expected is 4.5V, the scaling resistor should be 450kΩ. (see also paragraph (g) below).

d) Calculate the value of a scaling resistor for each a.c. test point on the same basis as in step (c). However if the a.c. test voltage is less than 0.7V r.m.s., refer to Section 3.4 and wire in either a single x 10 amplifier (0.07V to 0.7V r.m.s.) or two x 10 amplifiers in cascade (input less than 0.07V r.m.s.) before the a.c./d.c. converter. Then calculate the value on ten or one hundred times the input voltage, e.g. if the nominal voltage expected is 0.2V, one x 10 amplifier should be

used and the scaling resistor should be 200kΩ* (see also paragraph (g), below).

e) Where the test point presents a high source impedance, such that the input impedance of the A60 measuring system would produce an appreciable voltage drop, the user has the choice of compensating this by adjustment of the scaling resistor or avoiding the effect by inserting a high-input-impedance amplifier immediately after the test point.

Generally, adjustment of the scaling resistor is the simpler alternative, particularly where the measurement is at an a.c. test point and the troublesome component of the input impedance is its capacitance. In such cases the impedance-transforming amplifier would probably need to be constructed, since the input capacitances of all the built-in amplifiers are of similar magnitude to that of the a.c./d.c. converter.

There is no objection to adjusting the scaling resistor, provided that the loading of the test point does not affect the performance of the unit under test, e.g. by reducing the overload level, impairing the frequency response, etc. If any such effect is anticipated, an impedance-transforming amplifier should be inserted.

The loading imposed by the A60 on the test item depends on the type of measurement made, i.e. finite voltage or nominally zero, d.c. or a.c., and can be calculated from the information given in this manual.

If adjustment of the scaling resistor is required, the procedure detailed in Section 6, paragraph (g), will be found convenient.

---

* Unless a non-standard tolerancing is employed, see Section 4.3.8.

Test No.	STIMULUS			TEST SIGNAL				TOLERANCE				INTERNAL FUNCTIONS	EXTERNAL FACILITIES
	Voltage	Freq.	To	From	Via	To	Nom. Volts	Req'd	Prog'd	R_s	R_t		

Notes: 'Test Signal' columns:-
'From' denotes test point on test item.
'Via' denotes interface device in A60.
'To' denotes test input pin number in A60.

'Tolerance' columns:-
'Tolerance Programmed' will be used only when a non-standard tolerance is required (Section 4.3.8.)
'R_S' is the normal scaling resistor.
'R_T' is the additional tolerancing resistor needed for a non-standard tolerance.

'External Facilities' denotes any facility or interface device other than those built into the A60.

FIG. 20 EXAMPLE PROGRAM SHEET

f) When small voltages are to be measured with high accuracy, an allowance must be made for the input resistance of the measuring circuit (nominally 100Ω, ± 20% tolerance), i.e. 100Ω must be deducted from the calculated value of scaling resistor. If the scaling resistor is greater than 10kΩ, i.e., the voltage is greater than 100mV, then the error without this allowance is less than 1%.

g) The foregoing steps apply to checks of positive or negative voltages. If values about zero are to be measured, the basis of calculation for the scaling resistors depends on the tolerance programmed. Percentage tolerance has no direct significance in such measurements and its selection is therefore somewhat arbitrary. The required scaling resistor varies according to tolerance programmed as follows:

1% - 10MΩ per volt of permissible tolerance
2% - 5MΩ " " " " "
5% - 2MΩ " " " " "
10% - 1MΩ " " " " "

and so on pro rata.

The discrimination of the measurement varies directly with the value of tolerance. For example, with 1% tolerance the measuring period is 10 periods of the timing clock and hence the total tolerance range is resolved into only 10 steps, whereas with 40% tolerance the range can be resolved into 400 steps.

Thus the choice of tolerance is a compromise between loading of the test point and discrimination in measurement. There is usually a wide latitude in the choice and 10% (with a consequent scaling resistor of 1MΩ/V) is often convenient purely for ease of calculation.

4.2 Mounting the Test Item

Before starting to mount the test item, it is recommended that a trial assembly of the test panel, input/output board and program board should be carried out (Fig. 1). This will assist in visualising the optimum layout of the test sub-assemblies and wiring.

i) Remove the rear top cover plate, which is secured by three screws, and hinge forward the front top cover plate.

ii) Lift the two hinged levers adjacent to the black program board guides. Note that both levers should be lifted or depressed together to avoid slewing the program board. Place the program board on the guides, with the 24 function control tracks uppermost and their goldplated connector tabs to the rear, and engage the two metal studs on the guides with the holes in the board. Depress the two hinged levers; this will slide the program board back to engage with the edge-connector in the body of the A60.

iii) Mount the input/output board on the underside of the test panel, using the spacers supplied, with the edge-connector tabs protruding beyond the edge of the panel. The three mounting holes are countersunk on the upper surface of the test panel.

iv) Lay the test panel on its guides, input/output board underneath and at the rear, and push it back to engage the input/output board with the edge connector.

Note that, when the test panel is drawn forward and disengaged from its connector, two screws are revealed in the end brackets of the edge-connector assembly. (This refers to the inner pair, nearer the front of the instrument). If these are removed, the test panel assembly, when connected, can be hinged up into a vertical position.

With the instrument completely assembled, a sketch should be made of the layout of the test item and other sub-assemblies

required on the test panel, e.g., FET switches, interface amplifiers, connectors for external test equipment etc.

The depth available below the test panel is 25mm (1 inch) and no projection below the panel within 20mm (0.8 inch) of the left or right-hand edges is permissible.

Disassemble the test panel and program board and proceed to mount the test item. If the p.c.b. under test has an edge connector to which all necessary test points are brought out, then only a mating socket is required on the test panel to carry all the interface wiring.

Generally, however, the edge connector does not provide all the test points required and it is necessary to make contact with the printed circuit track by means of spring-loaded interface pins mounted on the test panel.

It is a great advantage if the test-point requirements are considered when the board is designed, so that test pads can be provided on the printed circuit track. To take account of mechanical tolerances in mounting the board on the test panel, a pad diameter of at least 2.5mm is recommended. A further feature that can be provided at the design stage is two locating holes in the board, positioned accurately in relation to the printed track, that can engage with pillars on the test panel to locate the p.c.b.

In many cases the board design is complete before test techniques are considered. If no test pads are provided, contact can be made to the printed track if this is sufficiently wide. If this method does not offer sufficient test points, component end connections can be used. For this purpose, cup-ended pins are preferable to the point-ended type (note that cup-ended pins are not supplied in the standard program kit).

A practicable minimum separation between pins on the test panel is 5mm and a reasonably uniform distribution of pins across the board area is desirable from the point of view of mechanical support.

It is not recommended that the pins be relied upon to pierce through solder resist or varnish on the p.c.b. track.

Typical methods of mounting the test item are illustrated in Fig. 21. At (a) is shown the preferred method of board location by two pillars on the test panel which engage with holes in the test item that are positioned accurately in relation to the printed circuit track. Also shown at (a) is one method of retaining the board and holding it in firm contact with the pins, i.e. the use of a toggle clamp and spreader plate. This method is particularly suitable for large boards. Thrust blocks are mounted on the spreader plate as required to hold the board flat.

It is not generally necessary to provide any support under the board apart from that given by the contact pins. Additional, unconnected pins can be fitted purely for mechanical support of any area of the board if thought desirable.

Fig. 21(b) shows alternative methods of board location and retention. When no positioning holes are provided, the board can be located by cheeks of s.r.b.p. or similar material against which the board edges abut. This method may introduce comparatively large tolerances into the relative positions of printed track and contact pins because of errors in the cutting of the circuit board edges. This must be allowed for when selecting contact points.

Two types of board retainer are shown at (b). These are a simple turn-button and a spring-loaded clip. Either is suitable for small p.c.b.'s for which edge-retaining is adequate.

Practically any printed circuit board or electronic sub-assembly within reasonable limits of size and weight can be accommodated and tested on the A60. For a heavy sub-assembly or for a circuit board that is even larger than the test area on the A60, it is possible to make a special interface that stands separate from the Testmatic. With this method, an interface

cable is made up to connect between the main instrument and the test jig.

To summarise the mechanical design rules for printed boards that are intended for testing on Testmatics:

1) On tracks where voltages are to be measured, provide a test pad at least 2.5mm in diameter. These can be anywhere on the track. (Note: if board space permits, put a test pad on every track, then the decision as to which to use can be taken later).
2) Provide a spacing of a least 5mm between pads.
3) Provide two locating holes accurately positioned relative to the printed track, not relative to the board edges.

The procedure for mounting the test item is as follows:

a) Assuming the test item is a printed circuit board, use one of these without any components fitted and mark the points on the track where tests are to be made or supplies fed in. Where holes do not already exist at such points, drill through track and board. (approximately 1mm diameter).
b) Clamp the P.C.B. on the test panel of the A60 and use it as a template to drill pilot holes for the contact pins and mark out for the mounting hardware.
c) Drill holes in the test panel to suit the spring-loaded pins to be used for contacts. For the pins supplied a No. 32 drill (2.95mm) will be found suitable.
d) Also drill the test panel to accommodate the mounting hardware. This can take a variety of forms to suit particular test items. Methods shown in Fig. 21 are suggested as suitable for most cases.
e) Drill the test panel to allow tag strips to be mounted so that components can be wired between them and the positions laid down for test points.
f) Fit the mounting hardware, tag strips and spring-loaded pins on to the test panel (see Fig. 22). Ensure that the

pins are inserted square to the panel face; the use of a hollow punch as an inserting tool will assist in this.

g) Where the test item incorporates plugs, sockets or other connectors, it is desirable to utilise these as part of the test. This minimises loading time and serves to check the wiring to such connectors.

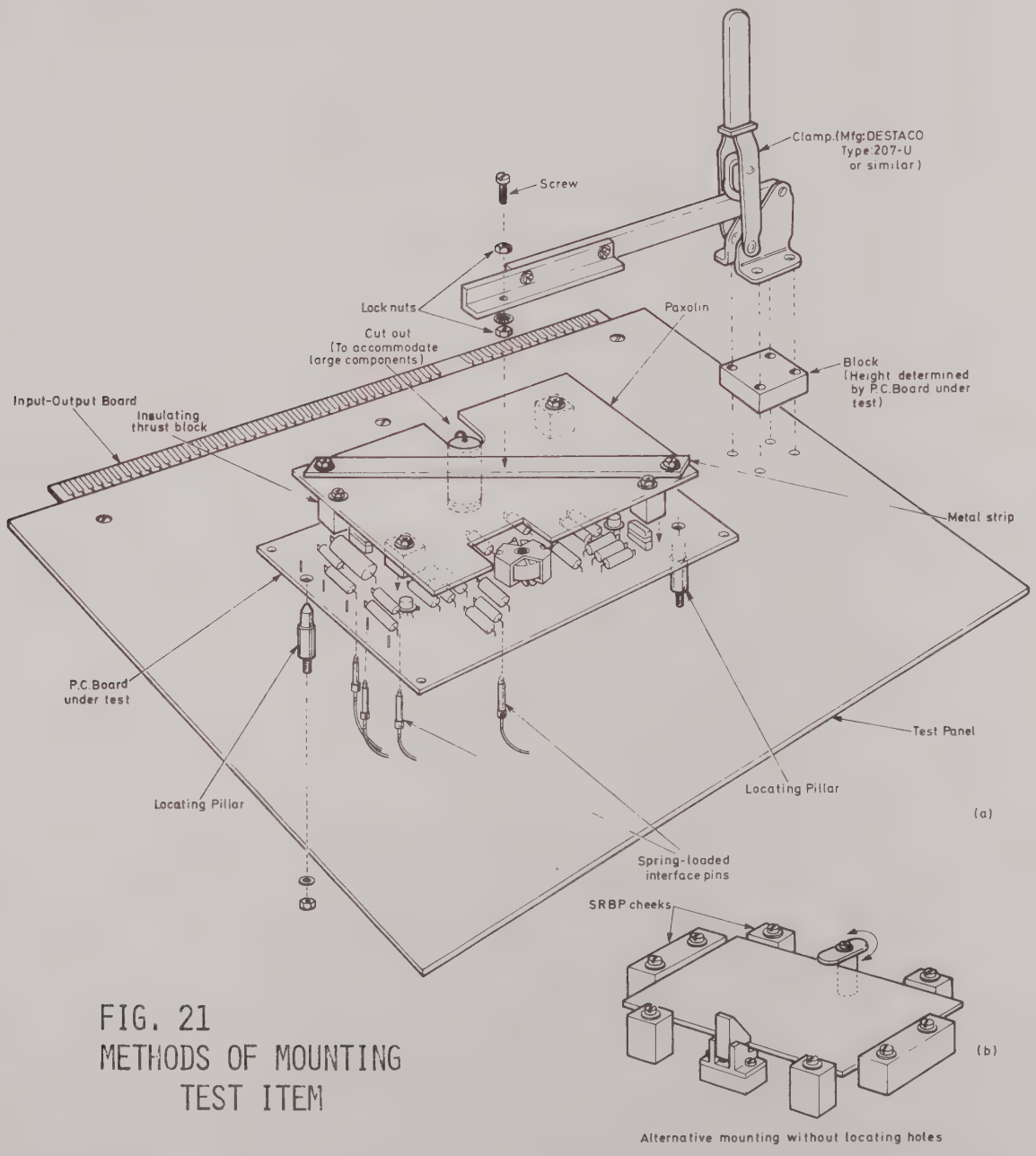


FIG. 21
METHODS OF MOUNTING TEST ITEM

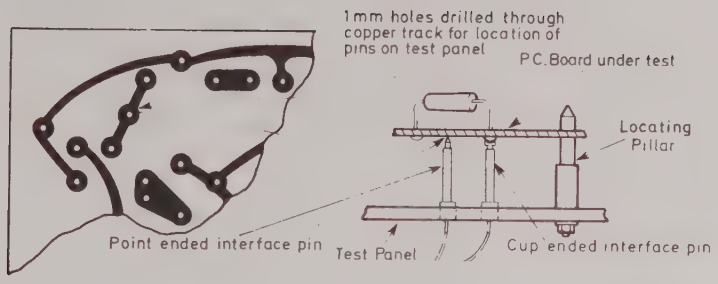

1mm holes drilled through copper track for location of pins on test panel
P.C.Board under test
Locating Pillar
Point ended interface pin
Test Panel
Cup ended interface pin

FIG. 22 LOCATING AND FITTING CONTACT PINS

4.3 Wiring the Program

Note: All wiring to the Input/Output board should be so arranged that it can be hinged away from the test panel, allowing free access to the underside of the board.

Wiring should be routed carefully, following normal engineering principles. Care should also be taken with earth connections to avoid earth loops and hum pick-up (see Section 4.3.2.).

The d.c.-measuring input circuit of the A60 is protected by shunt diodes and can safely withstand inputs up to 500V applied through scaling resistors greater than 10kΩ or up to 50mA applied through scaling resistors of 10kΩ or less. This refers only to the direct d.c.-measuring circuit, not to the amplifiers, a.c./d.c. converter or other interface devices that may be interposed between the test item and the basic measuring circuit.

Where it is required to measure the same output voltage on more than one test (i.e. the same nominal voltage from the same test point), it is permissible to use a common scaling

resistor and connect the appropriate input pins together. Section 7.6 shows an example of this on tests Nos. 11, 14 & 15. In such a case, it is still possible to program different tolerances for the individual tests.

4.3.1 Stray Capacitance Effects

Stray circuit capacitance can impair the accuracy of a.c. measurements, particularly at frequencies toward the upper end of the A60 range, unless appropriate precautions are taken when wiring the program.

For example:

i) The input capacitance of the measuring system can produce a voltage drop if the source impedance at the test point is high.

ii) Stray capacitance to the test point from wiring associated with the a.c. source can produce a.c. voltages in the measuring circuit that give rise to errors (Section 3.4).

iii) The capacitance between the contacts and associated wiring of a nominally open-circuit relay, or between the wiring of one set of relay contacts and another, can represent a significant susceptance. This can cause instability, if the capacitance is between the input and output of a high-gain amplifier, or an unwanted input to the measuring system if it is between an a.c. signal source and the measuring system input.

To avoid trouble from the causes listed above, certain rules should be observed:

a) Keep all a.c. wiring as short and direct as possible.

b) Do not form a.c. wiring into looms, unless screened cables are used.

c) Where difficulty is experienced or anticipated from (ii) above, the use of screened cable can help. It is generally preferable to screen the wiring of the inter-

ference source rather than that of the test input, as the latter will increase the input circuit capacitance.

d) Do not use the built-in relays of the A60 for switching a.c. signals unless tests have shown that no errors are introduced by the stray wiring and contact capacitances. For these purposes, FET switches are recommended (see below and Fig. 23).

e) Purpose-built impedance-transforming amplifiers (high Z_{in}, low Z_{out}), mounted close to the test item, will assist in obviating trouble from (i) or (ii) above.

The FET switch shown in Fig. 23 is suitable for a.c. signals at frequencies up to 20kHz with maximum instantaneous voltages within the range -10V to +15V. The 'on' resistance is 100Ω maximum, 'off' capacitance approximately 0.3pF.

The following points must be borne in mind when using switches of this type.

i) The E113 is symmetrical, i.e. source and drain are interchangeable.

ii) Either source or drain, but not necessarily both, must have an external d.c. path to the 0V line, or its equivalent, for example, the virtual earth of an operational amplifier.

iii) The FET will remain 'off' only while both source and drain potentials are more than 3V positive relative to the gate potential.

iv) If the source resistance R_s is high, the source potential may be pulled down by the current flowing through the 2.2MΩ gate resistor sufficiently to turn the FET 'on' when it is in the nominally 'off' condition. In such cases the gate resistor should be returned to the drain if R_L is lower than R_S.

4.3.2 0V Connections

Four separate '0V' connection areas are provided on the

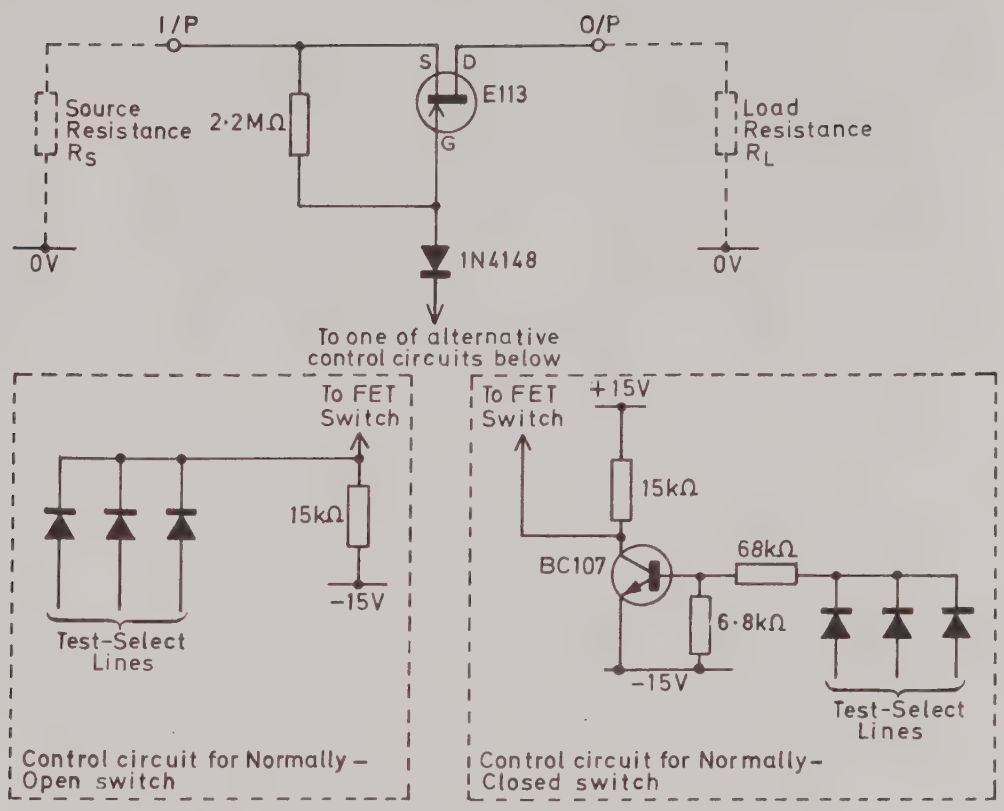


FIG. 23 FET SWITCH, NORMALLY-OPEN OR NORMALLY-CLOSED

Input/Output board, viz, the 'Signal 0V' track surrounding the test input pins, the '0V' track adjacent to the test power supply output pins, and the 'No. 1' and 'No. 2' 0V tracks which are directly associated with the No. 1 and No. 2 'X10' amplifiers.

These four areas are all connected together through the internal A60 wiring and hence are at substantially the same d.c. potential but, due to stray coupling with the power supplies and internal oscillator circuits, there are small a.c. potential differences between them which may be significant when measuring very small alternating voltages.

In order to minimise disturbance of such measurements by hum or by pick-up from the a.c. source, it is recommended that:-

i) The test unit earth-return line is connected to the Testmatic at only one point.

ii) The preferred connection point is generally the 'Signal 0V' track but, when the 'X10' amplifiers are used, it may be advantageous to return to the 'No. 1' or 'No. 2' 0V tracks (which are directly connected to the 'No. 1' and 'No. 2' amplifiers respectively).

iii) The 0V power supply return is used only for earthing ancillary equipment.

4.3.3. Scaling Resistors

The accuracy of a measurement made on the A60 can be no higher than that of the scaling resistor used and this, in turn, depends on the initial accuracy of the resistance value and its stability.

It is generally considered satisfactory if the scaling resistor tolerance is one tenth of the tolerance programmed for the measurement. This, however, may be difficult to achieve with close-tolerance measurements and some compromise may be necessary.

As far as initial accuracy is concerned; if a comprehensive stock of close-tolerance resistors is available, these can be selected on the basis of their nominal values. Where no such stock is available, resistors will have to be measured individually and the A60 can be used for this purpose.

Either fixed or variable resistors can be used for scaling. Variable types are quicker to set up and also facilitate subsequent adjustment at the program-proving stage. On the other hand they are generally less stable than fixed types and their settings can be changed inadvertently after installation. The following suggested measurement procedure assumes the use of fixed resistors but the adaptation to variable resistors is self-evident.

Section 7.2. describes methods of measuring resistors, primarily from the point of view of in situ measurements. For the measurement of scaling resistors, the same basic methods are suitable. If an adjustable D.C. power supply is available in which the output voltage can be adjusted down to zero, together with an accurate digital voltmeter to measure the output voltage, the circuit arrangement of Fig. 34(a) will probably be the most convenient method for measuring scaling resistors of all values.

The A60 should be on Test Point 60 and the '+ve' button depressed. The power supply negative terminal should be connected to the outer of the A60 'External Input' socket, and the positive terminal, through the protection resistor in series with

the scaling resistor to be measured, to the inner.

The protection resistor should be of such value as to limit the current through the measuring circuit to less than 50mA in the event of a short-circuited scaling resistor. With power supply voltages below 4V, corresponding to scaling resistors below 400kΩ, no protection resistor is necessary, as the input resistance of the A60 measuring circuit is sufficient to limit the short-circuit current to a safe value.

The power supply output voltage is adjusted to produce a current of 10μA through the scaling resistor (or through the scaling resistor plus the protection resistor if the value of the latter is sufficiently high to introduce a significant error). The scaling resistor is selected as the nearest stock value to that required. The percentage deviation indicated by the A60 can be used directly to derive the value of any trimming resistor required, as follows.

If the nominal value of the scaling resistor is R, and the indicated deviation is +x%, the trimming resistor required is

$\frac{x}{100 + x}$ R in series.

If the indicated deviation is -x%, the trimming resistor required is $\frac{100}{x}$ R in parallel.

This is illustrated in the following examples.

Example (i) To measure a d.c. voltage of 5.5 volts

Scaling resistor required: 550kΩ

D.C. supply voltage (allowing for 1kΩ protection resistor): 5.51V

Assume the indicated deviation is +4.4%, this can be corrected by a trimming resistor of $550 \times \frac{4.4.}{104.4}$ kΩ = 23.18 kΩ in series with the original resistor.

Example (ii) To measure a d.c. voltage of 50mV

Scaling resistor required 5kΩ

D.C. supply voltage 50mV (no protection resistor required)

Assume the indicated deviation is -3.4%, this can be corrected by a trimming resistor of

$5 \times \frac{100}{3.4}$ kΩ = 147 kΩ in parallel.

Whether the scaling resistors are re-checked after trimming or the nearest stock value to the trimmer required is added and assumed to be correct, will depend on the accuracy required. It should be borne in mind that when a trimming resistor with an error of 10% is added to correct an initial error of 4%, the final error in the combination is approximately 10% of 4% i.e. 0.4%.

Note that when scaling resistors are measured on the A60 by the method described above, the correction described in Section 4.1., sub-paragraph (f) for the measuring circuit input resistance is made automatically and does not have to be calculated separately.

As regards stability of value, the three types of resistor listed below will probably cover all requirements.

High stability: Metal Film 50 x $10^{-6}/^{o}C$ temperature co-efficient, (e.g. Allen Bradley, Type FC65 or Welwyn, Type 4033)

Intermediate: Metal Oxide, 2% tolerance, (e.g. Electrosil Type TR5)

General Purpose: Carbon Film, 5% tolerance, (e.g. Mullard Type CR25).

4.3.4 D.C. Scaling

Fit a multiway tag strip on the test panel and connect the d.c. scaling resistors as shown in Fig. 24. The sixty test inputs scanned by the program are numbered, on the Input/ Output Board, from 00 to 59.

Note: Scaling resistors should be placed near the test points to minimise any tendency towards instability of the printed circuit board under test.

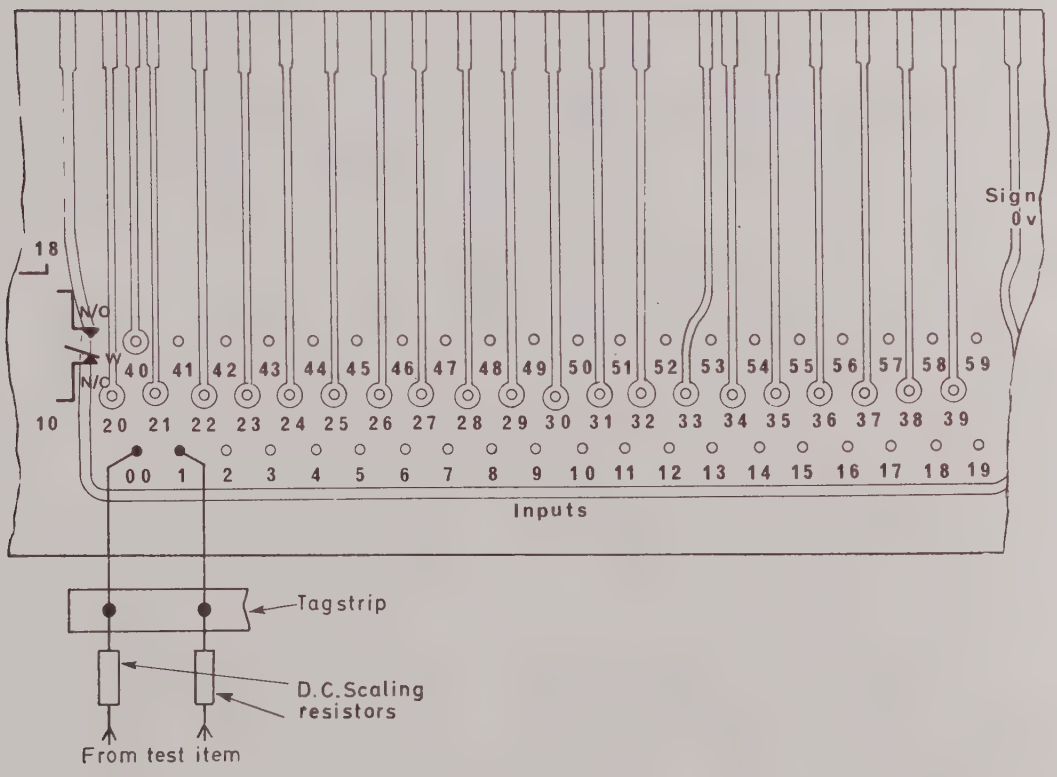


FIG. 24 D.C. SCALING RESISTOR CONNECTIONS

4.3.5. A.C. Scaling

A.C. measurements are made by connecting the a.c. signal from the unit under test to the A.C. to D.C. Converter (see Section 3.4) and applying the resultant d.c. to the test inputs as in 4.3.4. The scaling resistors are connected between

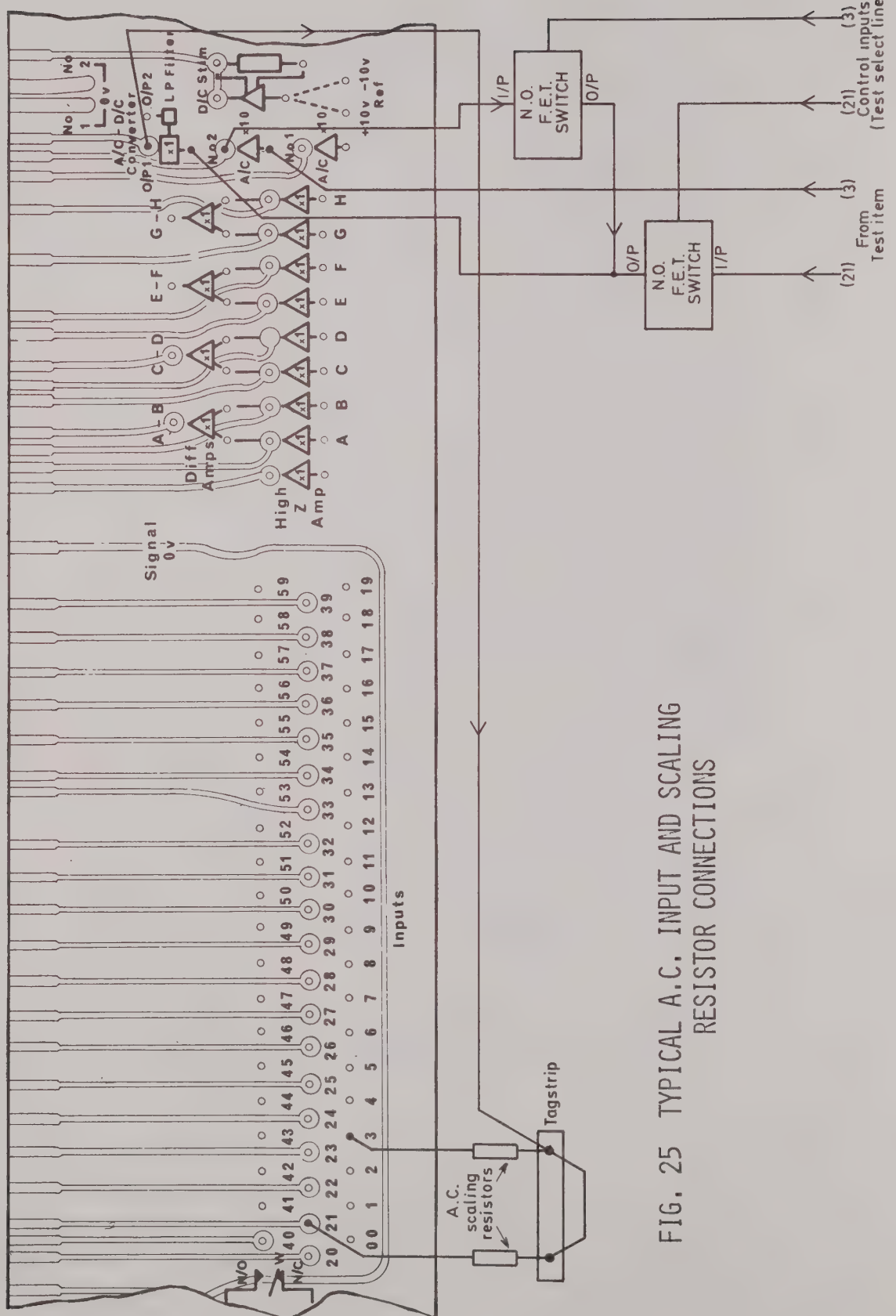


FIG. 25 TYPICAL A.C. INPUT AND SCALING RESISTOR CONNECTIONS

the output of the A.C. to D.C. Converter and the test inputs (see Fig. 25). The FET switches shown in Fig. 25 connect the X10 amplifier between the test point and the a.c./d.c. converter on Test 3 and connect the test point directly to the converter on Test 21. If there is only one a.c. input, the FET switches shown are not needed and the a.c. can be connected directly to the converter system.

For A.C. connections to the board under test it is recommended that where there is any doubt about circuit stability a resistor is placed close to the test point contact pin. It should be borne in mind that the presence of too large a resistor can cause a voltage drop owing to the cable and converter system input capacitance.

4.3.6. The Program Board

The programming for each test number is carried out on the Program Board (Fig. 26). This carries a matrix of 24 horizontal tracks on the top side of the board and 83 vertical tracks on the reverse.

The 24 horizontal tracks are the control inputs for the facilities marked alongside: Functions, Polarity, Tolerance and Relays. The vertical tracks labelled 0-59 are the test-select lines.

A facility is called when +15V is applied to the appropriate control input, i.e., one of the horizontal tracks. The test-select lines carry a potential of approximately -15V which changes to near +15V when the corresponding test number is called. Thus, linking a test-select line to a control input would cause the facility to be called at the corresponding test number.

Simple linking would, however, feed a +15V signal from one test-select line to another, which would render the system inoperative. To avoid this, linking must be by means of diodes and a separate diode must be used for each connection from a test-select line to a control input. Test-select lines must

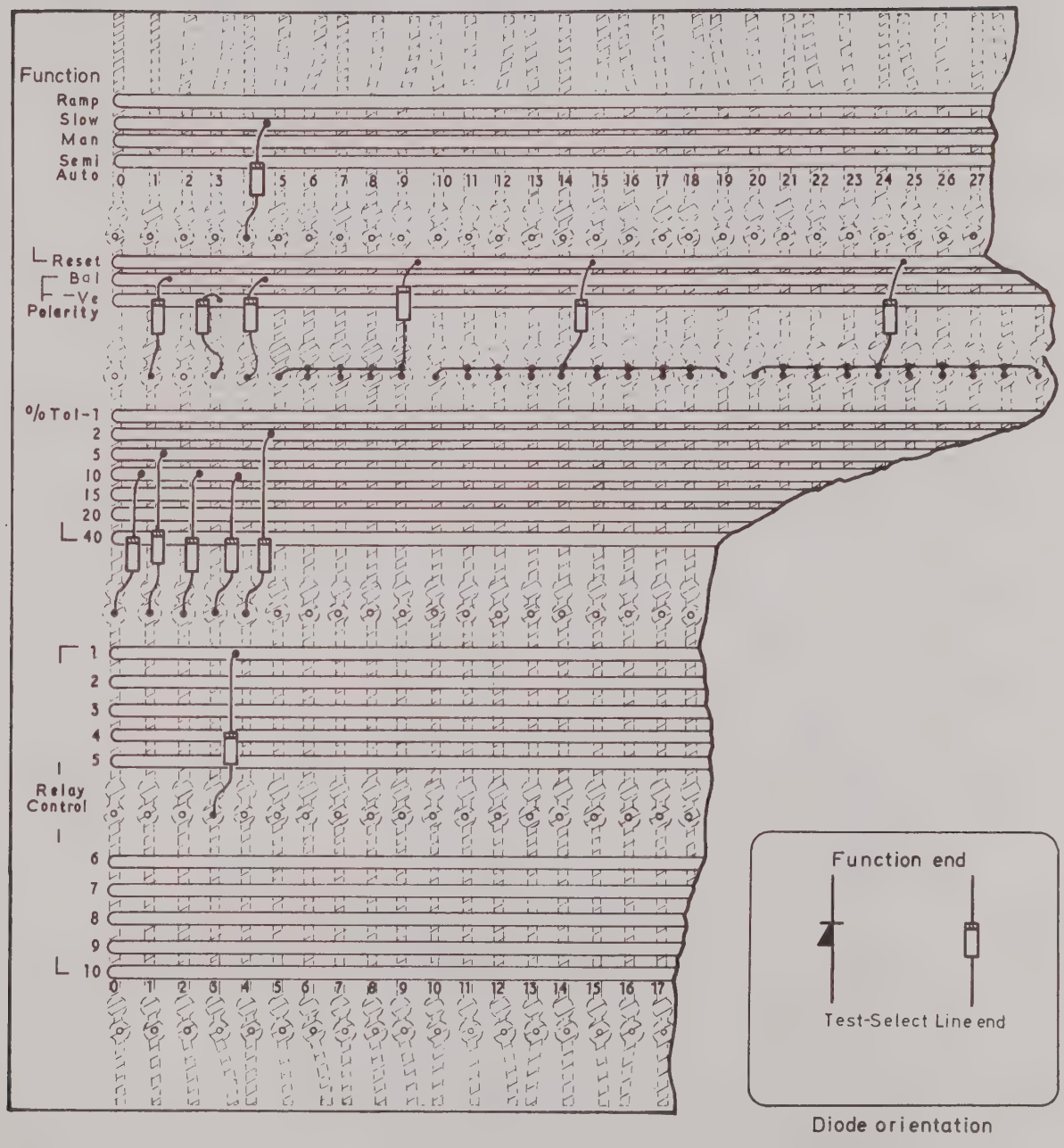


FIG. 26 TYPICAL PROGRAM BOARD CONNECTIONS

under no circumstances be directly connected together except where the tests concerned are not used.

Any low leakage silicon diode will be suitable, e.g. Texas 1N4148. In all cases the diodes must be electrically oriented with the anodes connected to the test-select lines and it is recommended that they are all inserted with the same physical orientation, as shown in Fig. 26.

The 61st vertical line, labelled 'All channels' is connected directly to the +15V supply. It can be used if a facility is to be called on all tests.

The vertical tracks numbered 1 to 22 on the reverse of the Program Board are the interconnection lines (see Section 4.3.10).

The test-select line voltage change can also be used to control ancillary equipment, FET switches, relays, indicator lamps etc. Two rules have to be observed.

Firstly, the resistance of the load connected between the test-select line and -15V must not be less than 1kΩ and, secondly, any reverse current flowing into the test-select line must not exceed 100μA. Disregarding either of these rules will render the A60 inoperative but will not cause any damage - the test-select lines are supplied from a current limited source and the current limit is between 30 and 40mA.

It is recommended that the load is returned to the -15V line to avoid sinking current into the test-select line. If, for a particular reason, a load is to be connected between a test-select line and 0V, it is <u>essential</u> to insert a diode in series with the load; the anode towards the test-select line.

To avoid the Testmatic stopping its automatic sequence at unused tests, the corresponding test-select lines should be connected through diodes to the 'Reset' track. Where many tests are not used, the corresponding test-select lines in any one defined group of ten may be linked together and a single diode used to connect each group to the 'Reset' line (see Fig. 26). The groups are 00 to 09, 10 to 19, 20 to 29, 30 to 39, 40 to 49 and 50 to 59.

Omit those points where tests are to be made and do not make any direct connections from one group to any other group. Do not make any connections to inputs of unused tests.

4.3.7. Polarity

A simplified circuit diagram of the A60 measuring system is shown in Fig. 2 (Section 2.1).

Normally, if no polarity is called, the S- gate is closed and the system is set for measuring a positive input current I_{in}. If I_{in} = 10μA, the reference current cancels the input current and 0% deviation will be indicated by the % meter. If I_{in} differs from 10μA, the difference will be measured and displayed as a % deviation from 10μA. Thus measuring a positive input current requires no programming for polarity.

If a negative input current is to be measured, S- has to be opened and S+ closed. This is achieved by connecting a diode from the appropriate test-select line to the '-ve' track.

Calling Balance (by connecting a diode to the 'Bal' track) opens S- and does not close S+. The A60 system then acts simply as a digital current meter and ± 10μA input current is displayed as ± 100.0%.

4.3.8. Tolerancing

With no tolerance selection made on the Program Board, the A60 will assume a fault condition for the particular test unless reset is called. Tracks are provided for selection of tolerances of 1%, 2%, 5%, 10%, 15%, 20% and 40%. Any of these values can be called up by connecting diodes from the test-select lines to the appropriate tolerance track (see Fig 26).

Certain other values can be programmed by connecting diodes from the test-select line to two or more tolerance tracks, the tolerance values thus selected being additive.

For example, to program for 25% tolerance, two diodes will be soldered in to call 5% and 20% tolerances. Not all combinations, however, are permitted, as some values are already obtained by adding.

To find whether a particular combination is permitted, it has to be borne in mind that the tolerances are originally expressed in BCD thus: 1, 2, 4, 10, 20 and 40%. The 8% and 80% tolerances are not available. Thus, 5% tolerance is derived internally by adding 1% and 4%, 15% is the sum of 1%, 4% and 10%.

It follows that, for instance, 6% cannot be obtained by adding 5 & 1, as 1 is already used to obtain 5. The table below shows the permitted combinations.

3	1 + 2	45	5 + 40
7	2 + 5	47	2 + 5 + 40
11	1 + 10	50	10 + 40
12	2 + 10	51	1 + 10 + 40
13	1 + 2 + 10	52	2 + 10 + 40
17	2 + 15	53	1 + 2 + 10 + 40
21	1 + 20	55	15 + 40
22	2 + 20	57	2 + 15 + 40
23	1 + 2 + 20	60	20 + 40
25	5 + 20	61	1 + 20 + 40
27	2 + 5 + 20	62	2 + 20 + 40
30	10 + 20	63	1 + 2 + 20 + 40
31	1 + 10 + 20	65	5 + 20 + 40
32	2 + 10 + 20	67	2 + 5 + 20 + 40
33	1 + 2 + 10 + 20	70	10 + 20 + 40
35	15 + 20	71	1 + 10 + 20 + 40
37	2 + 15 + 20	72	2 + 10 + 20 + 40
41	1 + 40	73	1 + 2 + 10 + 20 + 40
42	2 + 40	75	15 + 20 + 40
43	1 + 2 + 40	77	2 + 15 + 20 + 40

Asymmetrical tolerances on positive or negative test voltages should be programmed as symmetrical tolerances about the mean value of the permissible voltage limits. For example, a nominal

9V with permissible limit values of 12V and 8V would be programmed as 10V ± 2V, i.e. 10V with 20% tolerance.

Non-standard Tolerances

Any value of tolerance not obtainable by either of the methods so far detailed can be programmed as described below.

Calling a tolerance causes the A60 to assume a fault condition when the corresponding reading is reached or exceeded. If, for instance, 20% tolerance has been programmed, a fault is detected when the % meter reading is +20% or more, or -20% or less.

This means that, for positive polarity, a fault condition exists when Iin≥ 12μA or Iin≤ 8μA, for negative polarity, when Iin≤-12μA or Iin≥-8μA, and for Balance, when Iin≥2μA or Iin≤ -2μA.

By adding or subtracting a set current at the input to the integrator, any tolerance can be programmed. This is best demonstrated by an example. Let us assume that the A60 is programmed for 20% tolerance and a positive voltage measurement. The tolerance band is thus 8 to 12μA. If we now sink an additional current of 4μA into the test input, the tolerance band for the current from the test point becomes 4 to 8μA, i.e. 6± 2μA, i.e. 6μA ± 33.3%.

If 4μA is drawn from the test input, i.e. -4μA injected into it, the test input current tolerance band becomes 12 to 16μA. i.e. 14 ± 2μA, i.e. 14μA ± 14.3%.

The additional current is provided by connecting the test input to +10V or -10V reference via a suitable resistor, as shown in Fig. 27.

To program for non-standard tolerances choose the nearest standard tolerance available and calculate:

$$k = \frac{\text{standard tolerance programmed}}{\text{non-standard tolerance required}}$$

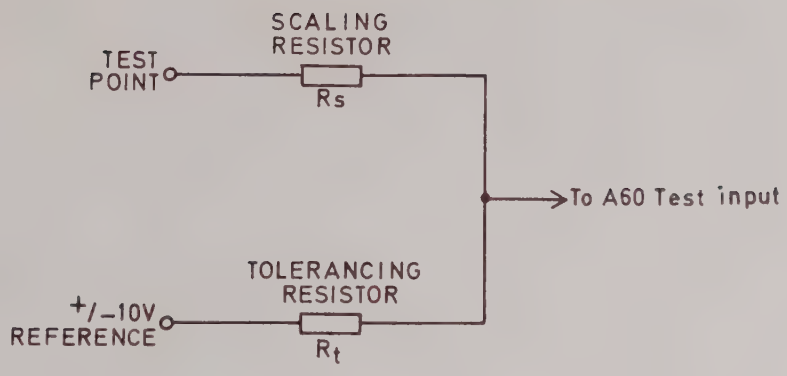


FIG. 27 NON-STANDARD TOLERANCING

Note that, with non-standard tolerancing, the indicated deviation on the digital display will differ from the true deviation of the voltage under test by the same factor k = Indicated Deviation/True Deviation.

For example, if k = 1.6, an indicated deviation of 8% would represent a true deviation of 5%.

If k>1, i.e. the required tolerance band is narrower than the standard tolerance used, the values of the resistors are

$$R_s = \frac{100}{k} \quad k\Omega/V$$

$$R_t = \frac{1}{k-1} \quad M\Omega$$

and R_t is to be connected to the reference voltage of opposite polarity to that of the Test Point.

It is not recommended that tolerances less than 0.5% are programmed. Limits below this level would not only approach the fundamental accuracy of the A60 itself but would demand very stringent control of the tolerance of R_t.

For k<1, i.e. a wider tolerance band, the values are:

$$R_s = \frac{100}{k} \quad k\Omega/V$$

$$R_t = \frac{1}{1-k} \quad M\Omega$$

and R_t is connected to the reference voltage of the same polarity as that of the Test Point.

If the tolerance band is about zero volts but not symmetrically disposed, it is convenient to consider the tolerance limits as symmetrically disposed about a notional mean value V_n, i.e. as $V_n \pm \Delta V$. 'Bal' is programmed and it is advisable to program 40% tolerance. The resistor values are then:

$$R_s = 0.25 \times \Delta V \quad M\Omega$$

$$R_t = 2.5 \frac{\Delta V}{|V_n|} \quad M\Omega$$

and R_t is to be connected to the DC reference of opposite polarity to that of V_n.

Examples: i) To program for test point voltage of +11.7V ±4%; program for 5% tolerance.

Then $K = \frac{5}{4} = 1.25$, $R_s = \frac{100}{1.25} \times 11.7 = 936\ k\Omega$

$R_t = \frac{1}{1.25-1} = 4\ M\Omega$, connected to -10V reference.

Alternatively, program 3% (2+1)% tolerance, then $k = \frac{3}{4} = 0.75$

$R_s = \frac{100}{0.75} \times 11.7 = 1560k\Omega$, $R_t = \frac{1}{1-0.75} = 4M\Omega$ connected to +10V reference.

ii) To program for 0V + 1.25V - 6.25V, consider it as -2.5V ± 3.75V. Program balance, 40% and then $R_s = 0.25 \times 3.75 = 0.9375M\Omega$, $R_t = 2.5 \frac{3.75}{2.5} = 3.75\ M\Omega$ connected to +10V reference.

4.3.9. Relay Control

The ten diaphragm relays are controlled from the Program Board. To call up the relays, connect diodes from the test-

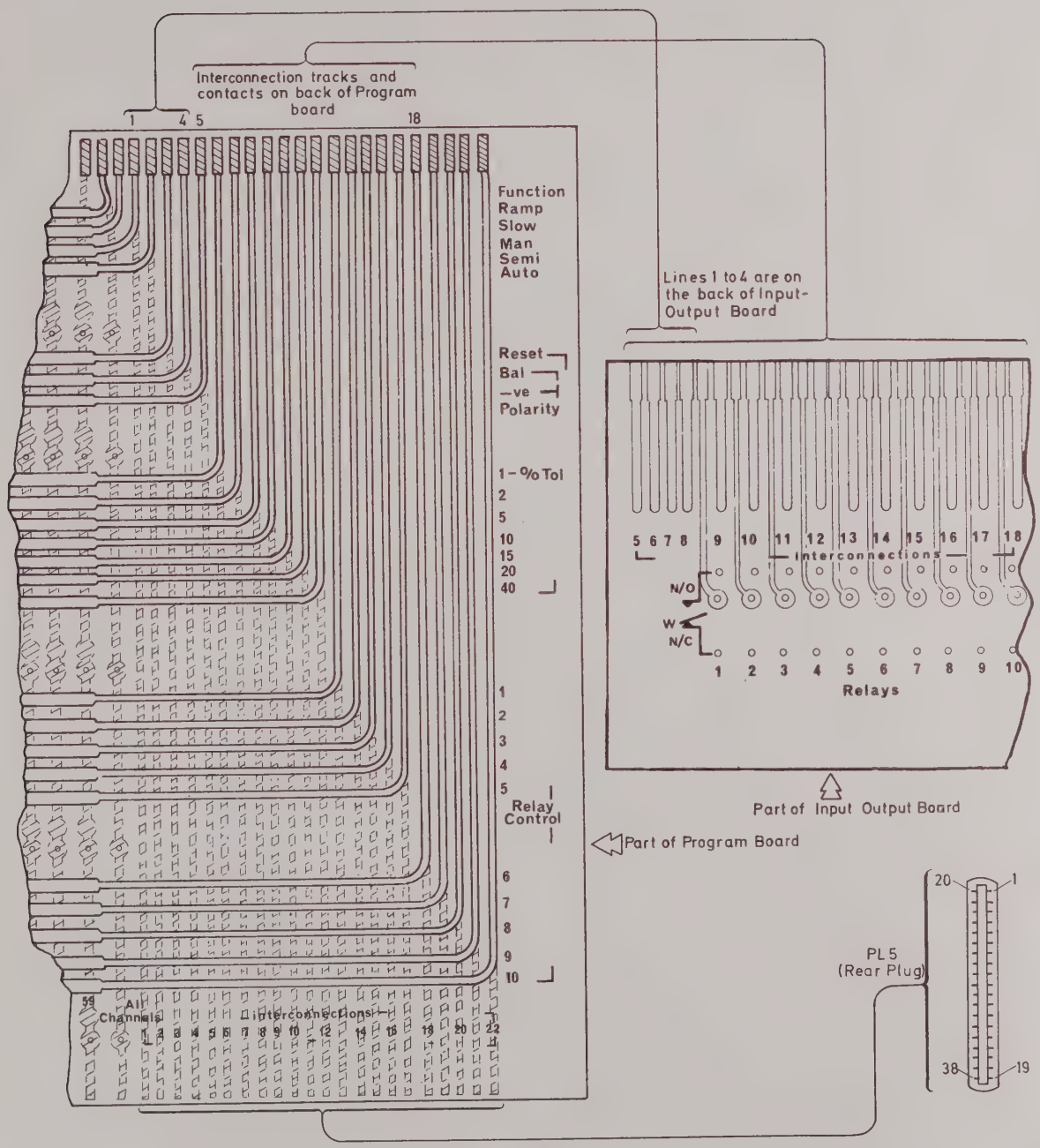


FIG. 28 INTERCONNECTION LINES

select lines to the appropriate relay control inputs (see Fig. 26). Note that one test can be connected to call up any number of relays up to ten, and that one relay can be called up by any number of tests.

4.3.10. Interconnection lines

There are 22 interconnection lines on the reverse of the Program Board, all of which connect to plug PL5 at the rear of the A60. (This is the left-hand item of the plug and socket pair as viewed from the rear of the instrument. Interconnection line No. 1 is connected to plug contact No. 1, line No. 2 to plug contact No. 2, and so on). Nos. 1 to 18 connect also to the Input/Output Board. These lines (see Fig. 28) can be used to connect, for instance, the relay contacts to operate an external service, a test-select line to an external circuit, or for any interconnection between the program and input/output boards.

4.3.11. Function Extension

The Program Board has track edge connections along both edges for the test-select lines and the interconnection lines. Thus, an edge connector can be fitted to the front edge of the board in order to give access to the test select signals, e.g. to drive external equipment etc.

4.3.12. Mode-changing and Test Delay

Basic selection of the operating mode is carried out by means of the front panel push buttons. However, certain changes of mode and timing can be selected for individual tests by connecting a diode from the test-select line concerned to the Function control input required, Ramp, Slow, Manual or Semi-Auto. Possible uses for this facility are as follows.

Semi-Auto - If A60 is operating in Auto mode, Semi-Auto can be selected only on those channels requiring adjustment, so that the 'holding on fault' characteristic of the Auto mode can be retained on the other tests.

Note that if any tests are programmed for 'Semi-Auto', the

use of the Recycle mode to locate intermittent faults may be impaired. If an intermittent fault exists on a Semi-Auto test at the moment when that test is being scanned, the A60 will stop. Should the fault then disappear the test cycle will resume and all trace of the fault will be lost.

Should Recycle operation be required for fault tracing, it is advisable to disconnect temporarily any diode(s) that program the Semi-Auto mode.

Manual - If A60 is operating in Auto mode, Manual can be programmed for a test(s) which requires more accurate setting-up, or where external tests have to be made. As soon as the test is complete, the Step button is pressed and the machine reverts to the Auto mode.

Note that if any tests are programmed for 'Manual' it is not possible to run the program continuously in the 'Recycle' mode as the A60 will stop at each Manual test until the 'Step' button is pressed. If 'Recycle' operation is required, the programming diodes calling up the 'Manual' mode should be temporarily removed and, if necessary to avoid a fault indication, the corresponding test inputs disconnected and 'Reset' programmed.

Ramp - Where the ramp output or sweep oscillator is used, the test sequence automatically waits for the ramp or sweep to complete. Thus, if the A60 is operating in the Auto mode it will pause when it comes to the test programmed for ramp. The ramp voltage (or the frequency) will rise and measurements will be taken at the Auto or programmed rate during the ramp cycle. When the ramp reaches its threshold level, the A60 will automatically step on to the next test and the Auto mode will be resumed. Note that the ramp must not be used in immediately consecutive tests.

Slow - In normal operation, at the instant when a control line switches from -15V to +15V, the internal control circuits of the A60 initiate the measuring sequence illustrated in Fig. 29.

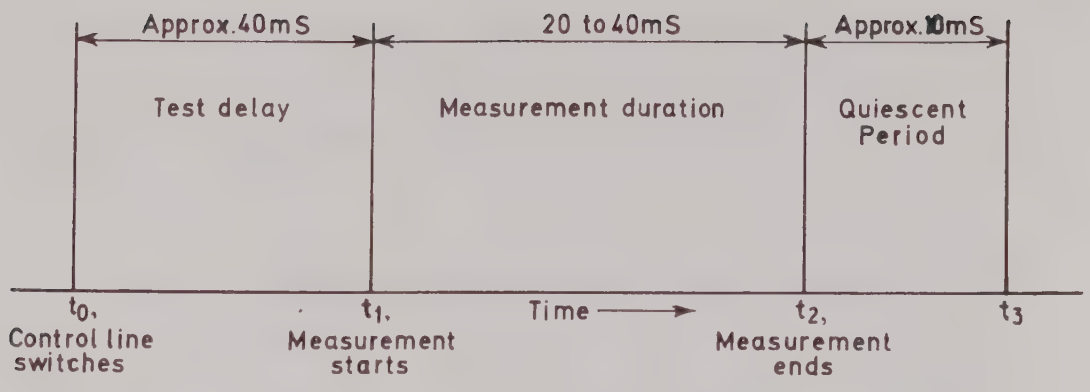


FIG. 29 TEST PERIOD TIMING SEQUENCE

When a longer-than-normal test delay is required, e.g. when the test item needs time to settle after the application of a stimulus or when the sample-and-hold is in use (Section 3.9), the test delay can be lengthened by one of two methods.

i) Connect a diode from the appropriate test-select line to the 'slow' control input and insert, on the input/output board (Fig. 30) a 'speed' resistor of value determined from Fig. 31.

If several different time delays are required at different tests, the 'speed' resistors, each in series with its individual diode, (wired anode to test-select line), may be wired from the appropriate test-select lines via a common interconnection line to the timing input terminal shown in Fig. 30. In this case, no speed resistor is connected on the Input/Output board.

Alternatively, several different resistors may be switched in using relays.

The curve of Fig. 31 is approximately correct for delays of up to 2 seconds. Delays of up to 5 seconds can be obtained with reduced accuracy but above this value the timing circuit may fail to trigger, especially in conditions of high environmental temperature or humidity, owing to leakage in

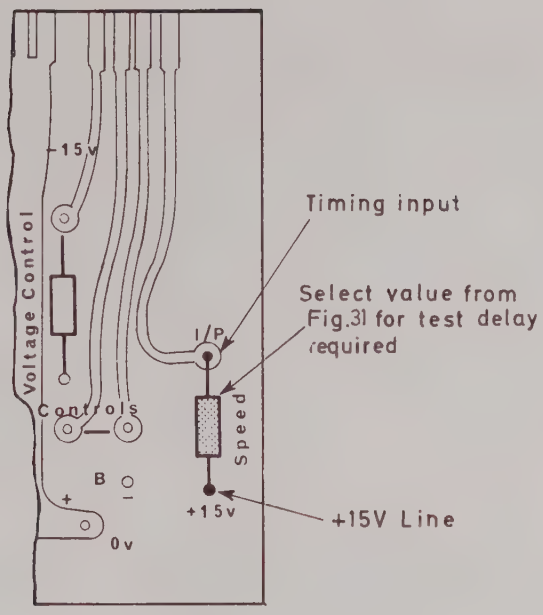


FIG. 30 TEST DELAY ("SPEED") ADJUSTMENT

the timing circuits.

ii) Longer time delays or external triggering of the measuring sequence can be obtained by programming 'slow', omitting the 'speed' resistor on the input/output board, and applying the +15V required to trigger the measurement process directly to the timing input (Fig. 30) from an external source. A circuit suitable for delays up to 10 seconds is shown in Fig. 32.

For even longer delays, the circuit of Fig. 33, using a relay and the high input impedance amplifier can be employed.

If the start of the measuring sequence is to be related to a particular event (e.g. when measuring time periods, see Section 7.4), the triggering step can be generated by the event itself, using a suitable interface.

If either of these techniques of applying +15V directly to the timing input is adopted, it should be noted that a delay of approximately 200ms occurs between the application of the

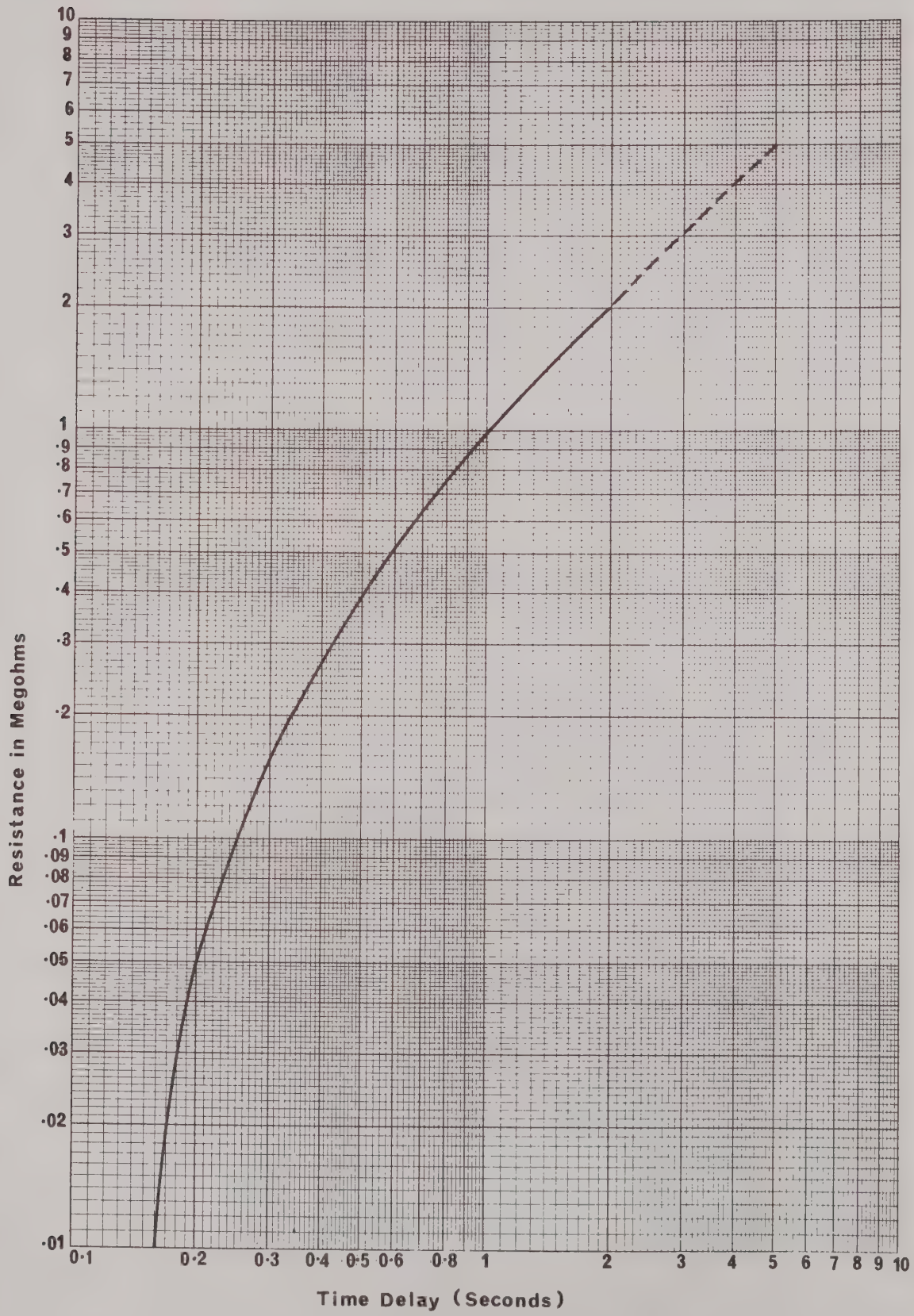


FIG. 31 "SPEED" RESISTOR SELECTION CURVE

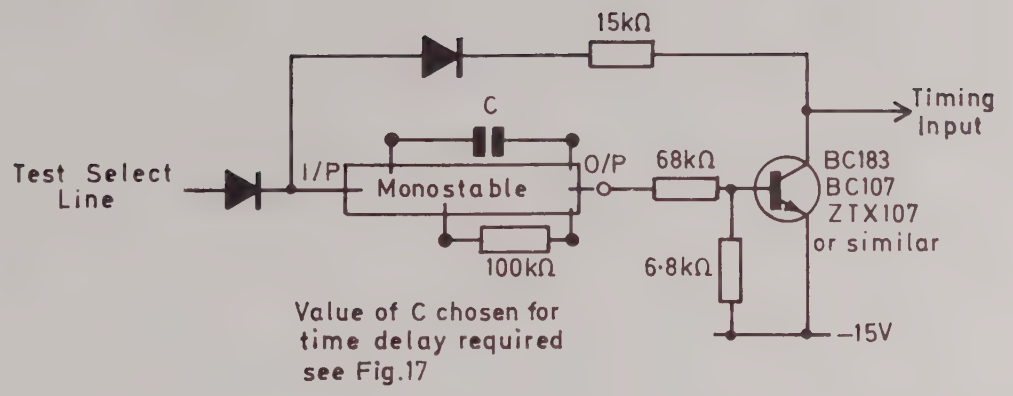


FIG. 32 TIME-DELAY CIRCUIT USING THE MONOSTABLE

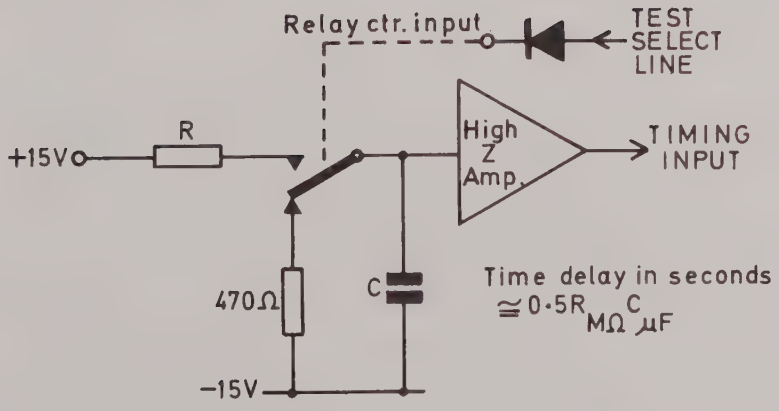


FIG. 33 TIME-DELAY CIRCUIT USING THE HIGH-INPUT-IMPEDANCE AMPLIFIER

triggering input and the start of the measurement.

Note 1: If 'Manual' is selected by the panel push-button (but not if it is programmed), any 'Slow' programming is over-ridden and the A60 carries out repeated measurements at intervals of about 80ms throughout the period of the test. The deviation display is updated at each measurement but the fault display is triggered if any measurement is outside the programmed tolerance. This means that any test that requires a long test delay in order for the test conditions to settle may indicate 'Fault' if the A60 is operating in the push-button-selected Manual mode.

Note 2: The Test Number display is updated as soon as a new test is selected but the % Deviation display is updated only when the measurement has been completed. There is thus a delay period during which the Test Number display shows the number of test N while the % Deviation display shows the result of test N-1.

When the program is proceeding at normal speed, this delay period is of the order of 0.1 second and is barely noticeable. When Slow or Ramp is programmed, however, it can last for up to a minute or more and may cause confusion if the operator is not forewarned.

5 PRINTER CONNECTION & CONTROL

Parallel BCD printer drive outputs, together with control lines, are provided on socket SKT6 at the rear of the A60. (This is the right-hand item of the plug and socket pair as viewed from the rear of the instrument). The connections are as follows:

SKT6 Pin	Service	SKT6 Pin	Service
1	-15V	21	-15V
2	40 (Test No. Selected, BCD)	22	40 (Percentage Tolerance Programmed, BCD)
3	20	23	20
4	10	24	10
5	8	25	-15V
6	4	26	4 (Percentage Tolerance Programmed, BCD)
7	2	27	2
8	1	28	1
9	80 (Percentage Deviation Measured, BCD)	29	-15V
10	40	30	Print Command = '0'
11	20	31	Print Command = '1'
12	10	32	Fault = '1'
13	8	33	-ve Deviation = '0'
14	4	34	-10V
15	2	35	Busy from Printer = '0'
16	1	36	Inverter O/P
17	0.8	37	Inverter I/P
18	0.4	38	100% Deviation Measured
19	0.2		
20	0.1		

It has to be borne in mind that the A60 internal logic is referred to the -15V line, i.e., logical '0' is at -15V and logical '1' at -10V (subject to the usual TTL tolerances) with respect to mains ground. It is therefore essential that the printer used is compatible with this.

The 'Busy' line from the printer holds the A60 on the test being measured until the print is complete for that test. The 'Busy' signal required is a logical '0'. If the printer 'Busy' is logical '1', the inverter (pins 36 and 37) should be used, i.e. pins 35 and 36 linked together and the printer 'Busy' output connected to pin 37. Note that this is a separate inverter from that to which access is obtained on the Input/Output board. If there is no 'Busy' signal output from the printer, program a suitable delay using the SLOW facility (see Section 4.3.12).

The Fault output at pin 32 is at logic '1' when the tolerance set for a test is exceeded; this may be used, for example, to give a red printout. Logic '0' at pin 33 indicates a negative polarity of the percentage error, and logic '1' indicates a positive polarity.

The -15V supply is available on pins 1, 21, 25 & 29 and the -10V on pin 34, giving a 5V supply at up to 50mA for powering external logic if required.

6. PROVING THE PROGRAM

a) Insert the Program Board in the A60 and move the levers at the sides to push it home into its socket. Lay the test panel, with the input/output board bolted to its under side, on the support rails.

Check the clearance of the wiring and components beneath it, and then push it back firmly to engage the socket.

b) Locate a proven test item in position.

c) Switch on the A60, select Manual and allow 30 seconds warm-up time.

d) Press the Start/Reset button. Test number 00 will be displayed. Check that the percentage deviation reading is satisfactory.

e) Press 'Step' to obtain test number 1. Check that the percentage deviation reading is satisfactory and repeat the process for all programmed test points. When a ramp or sweep frequency test occurs, measurements will be taken at the normal Auto intervals (or Slow if programmed) applying, for each measurement, the value of tolerance programmed for the test. The ramp is not repetitive and it would be necessary to reset to 00 to repeat the test.

f) Assuming a fault-free test item, and no programming errors, each reading should be near 0% or deviate from this only by an acceptable amount. If this is so, confirm that testing proceeds correctly in the intended mode (Auto, Semi-Auto, etc.) and that the printer, if fitted, produces the anticipated print-out.

g) If, during the Manual checking on any test number, the deviation indicated by the meter is considered excessive or the 'Fault' indication is given, first verify that the assumed test voltage, the value of scaling resistor and the tolerance programmed are correct. If they are, the source of the error may be:

i) loading of the test point by the measuring system resistance, or capacitance if an a.c. test (see Sections 4.1 and 4.3.1),

ii) no allowance having been made for the input series resistance of the A60 d.c. measuring circuit, if the d.c. voltage to be measured is small (see Section 4.1),

iii) self-oscillation in the unit under test (see Section 4.3.1),

iv) stray pick-up of hum or a.c. in the test voltage input wiring (see Section 4.3.2),

v) an error in the program wiring (see paragraph (i) below).

If the error arises from cause (i) or (ii) above, it may be corrected by adjusting the value of the scaling resistor; the reading of the A60 deviation meter can be used to derive the value of the trimming resistor required. The method for doing this is discussed fully in Section 4.3.3 but is recapitulated briefly below for convenience.

If the indicated deviation is -x%, the required correction is provided by a parallel resistor of value $\frac{100R}{x}$.

If the indicated deviation is +x%, the required correction is a series resistor of value $\frac{xR}{100+x}$.

Thus, for example, if the original scaling resistor were 180kΩ, and the error -0.6%, the shunt resistance required is: $180k\Omega \times \frac{100}{0.6} = 30M\Omega$. Had the reading been high instead of low, it would merely be necessary to introduce a series resistor of $180k\Omega \times \frac{0.6}{100.6} = 1.074k\Omega$.

h) The procedure described above verifies that a test unit within specification limits will pass satisfactorily through the test sequence. To establish also that a unit with any parameters outside specification will produce the required failure indication, it is advisable to check that the correct tolerances have been programmed by the method outlined in paragraph (j) below.

i) A common error in wiring a program is the connection of a diode with its polarity reversed (also, wrongly marked diodes

are not unknown). This causes the +15V test-select signal not to appear at points where it should be on the test in which the diode is wrongly connected, and may cause it to appear where it should not be on other tests.

If any anomalous behaviour of the A60 is observed, the test-select and function control line voltages should be checked. +15V (approximately) should appear on the test-select and function control lines selected for that test and on no others. Of course, this check must be made with the A60 at the test number on which the unusual behaviour is observed.

j) Situations may arise where a program has been built, using calculated voltages or a prototype which is no longer available, and proving is required before production begins. In such instances, a step-by-step check (Manual mode) can be made using d.c. and a.c. supplies, a potentiometer and a digital voltmeter to produce and measure each anticipated voltage. By off-setting the voltage, the programmed tolerances can also be checked.

The output from the above equipment is connected to each contact pin on the test panel in turn as the program is manually stepped through.

7 ADDITIONAL INFORMATION

7.1 Current Measurement

A small value resistor should be introduced in series with the appropriate part of the circuit such that one side of the resistor is at 0V, otherwise a differential amplifier will be needed. The voltage developed across the resistor is a measure of the current flowing in that part of the circuit, and is checked by the A60 in the usual way, i.e. via a scaling resistor. A desirable voltage drop would be in the region of 1V, but values down to 100mV or even 10mV can be used with reduced accuracy (at 10mV, about ± 2%). If necessary, one of the relays can be used to bypass the resistor for all tests except the current measurements. In the case of a.c. currents, the measurement would be made using the AC to DC Converter to measure the voltage across the series resistor.

It will usually be found more convenient to use a series resistor of (say) 1Ω, 100mΩ or 10mΩ and choose the scaling resistor to suit the voltage developed. For example, if the normal current is 400mA, a series resistor of 100mΩ would produce a voltage drop of 40mV. For this the total scaling resistance required would be 0.04 x 100k = 4kΩ. With such a relatively small value it would be necessary to allow for the input resistance of the measurement circuit, nominally 100Ω with a tolerance of ± 20Ω. Thus, the resistor required would be 3.9kΩ.

7.2. Resistance Measurement

Many resistors will be checked as a result of d.c. voltage measurements. For those which are not, special provision for measurement can be made provided that they are not part of a d.c. -connected network or shunted by semi-conductor devices. The circuit arrangements to be used, which vary depending on the value of the resistor, are shown in Fig. 34. In all cases, the voltage and polarity of the supply must be chosen with due regard to the rating of any other components, such as electrolytic capacitors, present in the test circuit.

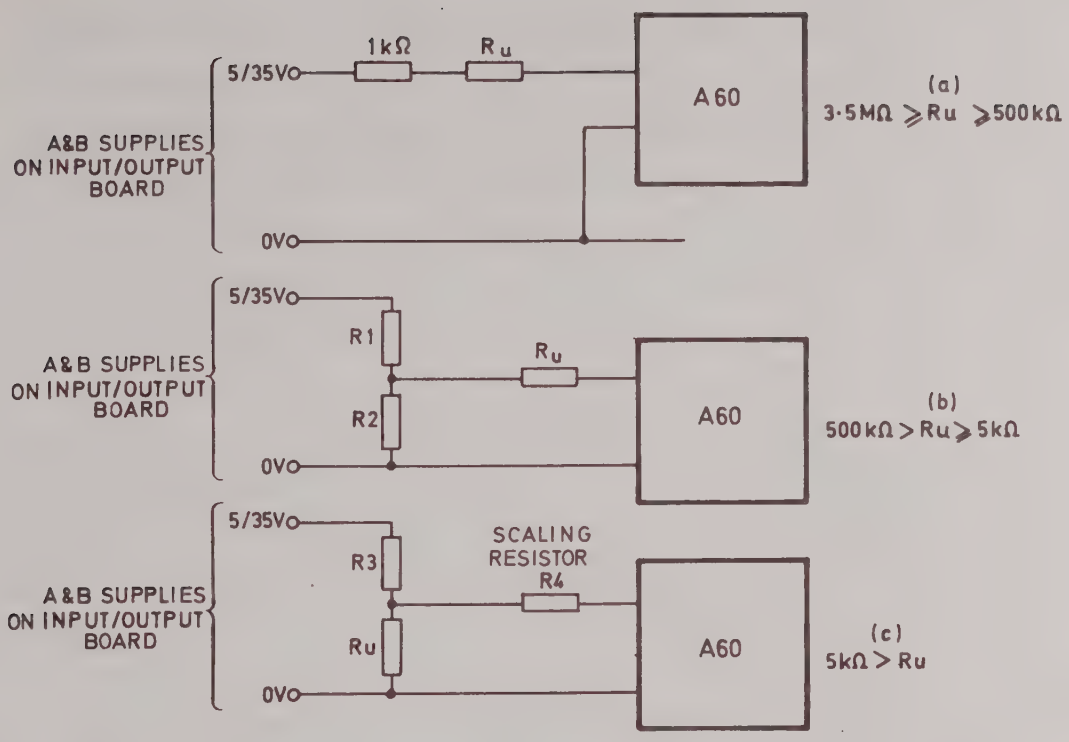


FIG. 34 RESISTANCE MEASUREMENT

High value resistors For values of the resistor under test (Ru) between 3.5MΩ and 500kΩ, the arrangement of Fig 34(a) is used. The supply voltage is adjusted to produce a current of 10μA through the nominal value of Ru. The series 1kΩ is inserted only to protect the A60 by limiting the short-circuit current in the event of a faulty test resistor. Ignoring the error introduced by this protection (which does not exceed 0.2%), the A60 indicates directly the percentage deviation of the test resistor.

Medium value resistors For resistor values between 500kΩ and 5kΩ, the arrangement of Fig. 34(b) is used. This is identical in principle with that in (a) except that the input voltage is derived from the potential divider R_1, R_2. In order that the indicated deviation shall be accurate, it is necessary that $\frac{R_1 R_2}{R_1+R_2} \ll$ Ru,

i.e., that the test resistor be fed from a sensibly constant - voltage source. Also R_1 should be sufficiently high in value to protect the A60 against a short-circuit test resistor.

These two requirements are easy to satisfy. For example, if the supply voltage is 10V and R_1 is made 1kΩ, the range of R_u between 500kΩ and 5kΩ can be accommodated by adjusting the value of R_2 between 1kΩ and approximately 5Ω and $\frac{R_1R_2}{R_1+R_2}$ will be approximately 0.1% of Ru.

Low value resistors For values of Ru below 5kΩ down to 1Ω (or to 10mΩ with reduced accuracy), the circuit is as shown in Fig. 34(c). In order that the indicated deviation be as accurate as possible, the requirement in this case is that $\frac{R_3R_4}{R_3+R_4} \gg Ru$, i.e. that the test resistor is fed from as nearly as possible a constant-current source. It helps in meeting this requirement if the supply voltage is made as high as possible and the scaling resistor (R_4) is approximately equal to R_3. The deviation indicated by the A60 may, however, differ significantly from the actual deviation in the value of R_u, particularly when the nominal value of Ru is towards either end of the range covered by this circuit arrangement or when the supply voltage is low.

For this reason, the recommended programming procedure is:

i) Calculate the values of R_3 and the scaling resistor R_4 from the formula $R_3 = R_4 = \frac{\sqrt{V.Ru}}{10}$ kΩ, where V is the supply voltage in volts and Ru the resistor to be measured in ohms.

ii) Fit, in turn, the largest and smallest acceptable values for Ru, note the deviations indicated by the A60. If these vary either side of the nominal value by substantially different amounts, the scaling resistor can be adjusted.

iii) Programme the tolerance appropriate to the deviation indicated in (ii) above.

If the highest accuracy is required, when using the circuit arrangements shown in Fig. 34(b) or (c), allowance should be made for the input resistance of the A60 (100Ω ± 20%). This will make Ru (Fig. 34b) appear to be approximately 100Ω higher than its true value, and in the arrangement of Fig 34(c) will require R_4 to be made 100Ω lower than its calculated value.

7.3. Frequency Measurement

The monostable can be used as a frequency-to-voltage converter. The principle of operation is simple: if the monostable is made to produce a short pulse for each period of the input waveform, then the averaged DC output is proportional to the input frequency and independent of the input voltage and waveform shape.

The monostable requires a clean rectangular input waveform and a shaping stage is usually necessary. A Schmitt trigger is suitable for this purpose and the full circuit diagram is shown in Fig. 35.

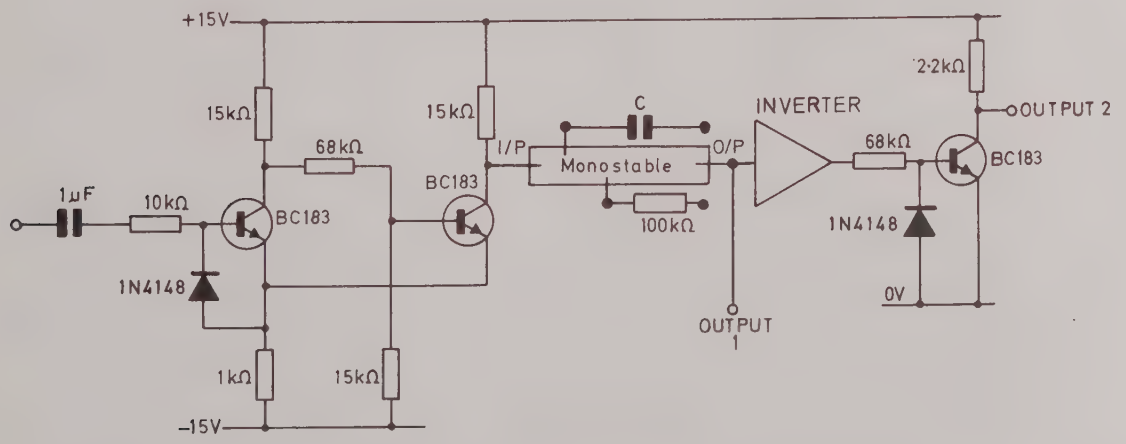


FIG. 35 FREQUENCY-TO-VOLTAGE CONVERTER: CIRCUIT DIAGRAM

Output O/P1 is referred to the -15V line which means that the d.c. output voltage is near -15V for f = 0 and rises with increasing frequency up to near +15V for the upper frequency of the range. If there are no objections to this, the subsequent part of the circuit,

i.e. the inverter and the following transistor can be omitted.

Output O/P2 produces a unipolar (positive) signal, positive-going with increasing frequency.

Whichever output is used, the a.c. component has to be filtered out. This is conveniently done by splitting the scaling resistor into two equal parts and inserting a smoothing capacitor, C_s, at the junction (Fig. 36).

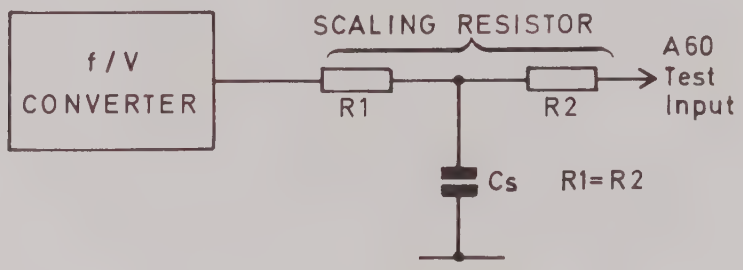


FIG. 36 SMOOTHING CIRCUIT FOR FREQUENCY-TO-VOLTAGE CONVERTER OUTPUT

The usual rule $RC_s \gg \frac{1}{2\pi f}$ applies, where $R = \frac{R1}{2} = \frac{R2}{2}$, and a delay of 5RC must be programmed to allow the output to settle.

The converter requires a minimum of 1V r.m.s. input and will safely accept up to 30V. For higher inputs a suitable resistor in series should be used to limit the input current to a safe value of about 3mA; for lower inputs one or two x10 amplifiers can be used.

The value of the monostable timing capacitor, C (Fig. 35), is a function of the required frequency range, approximately,

$$C = \frac{10}{f}$$

where f is the upper limit frequency of the range in kHz and C is expressed in nanofarads.

The output d.c. voltage is approximately

$$V_{op1} = 2.3fC$$

$$V_{op2} = 1.15fC$$

where V is in volts, f in kHz and C in nanofarads.

7.4. Time Interval Measurement

Time interval can be measured by means of the ramp and the sample-and-hold, using the circuit shown in Fig. 37.

At the beginning of the time interval T (t_1) the A control voltage changes from -15V to +15V, starting the ramp. This can be the signal from the test-select line, if selecting the test starts the time interval to be measured.

At the end of the time interval (t_2) the B control voltage has to change from -15V to +15V.

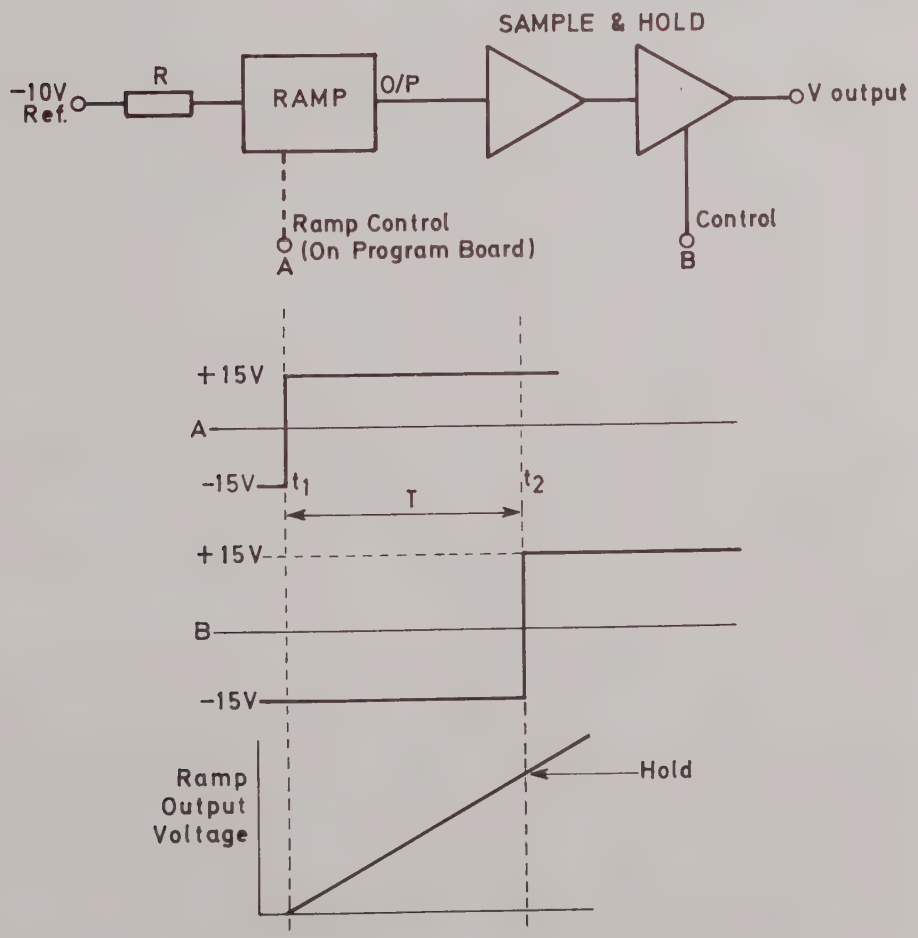


FIG. 37 TIME-INTERVAL-TO-VOLTAGE CONVERTER: SIMPLIFIED CIRCUIT AND CONTROL WAVEFORMS

This B control signal has to be derived, using a suitable interface, from the event marking the end of T.

At the same time, t_2, the A60 measuring sequence can conveniently be started by applying the B waveform to the A60 timing input (Section 4.3.12.).

The ramp input resistor R should be selected to obtain a nominal ramp period about 25% longer than the longest anticipated time interval T (Section 3.5).

The output DC voltage is

$$V = \frac{4550}{R-4.7} \quad T$$

where V is in volts, R is in kΩ and T is in seconds, with a possible error of about ± 5%.

If only an approximate measurement is required and T is one second or longer, the Sample & Hold may be omitted and the output taken directly from the Ramp. The control voltages will be as before, the B waveform being applied to the A60 timing input. In this case, however, the A control voltage must stay at +15V for at least 250 msec after t_2.

The additional error in this method arises from the fact that the voltage measurement is made about 200ms after t_2 and that during this 200ms delay period the ramp voltage continues to rise. The apparent duration of the measured time interval will therefore be about 20% high when T is one second, the error decreasing as T increases.

7.5 Use of Test Point 60

At the end of the scanning cycle (except in the Recycle mode) the instrument will stop at test point 60. In this position, and with Manual selected, the front panel coaxial socket (External Input) provides direct access to the meter circuit. This facility allows the use of the 'Deviation' meter as a digital, 10μA f.s.d., current meter, as a 100kΩ/V d.v.m. when used with a suitable scaling resistor, or as an ohmmeter when used with a suitable d.c. power supply.

'+ve', '-ve' or 'Bal' may be selected by the front panel buttons.

It is subject to the same protection against overload as quoted for other test points (see Specification, Section 8).

For voltage measurement, the A60 is generally operated in the 'Balance' mode and the value of scaling resistor depends on the voltage range to be measured, as follows:

0 to 1V = 100kΩ, 0 to 10V = 1MΩ, 0 to 100V = 10MΩ.

7.6 Example of a simple Test Program

The PCB under test, the circuit diagram of which is shown in a broken-line box in Fig. 38, is a 10W audio-frequency amplifier. Fig. 38 also shows the arrangement of FET switches and Testmatic facilities used for the test program. The program sheet is shown in Fig. 39 and the program board wiring in Fig. 40. The test sequence is as follows:

Test 0: The quiescent direct voltage level of the output point is adjusted by means of R1. The A60 is programmed in Semi-Auto for this test and as soon as the voltage in question is brought within ± 2% limits, the A60 steps automatically on to

Test 1: DC level check.

Test 2: Again is Semi-Auto. The quiescent current of the output stage is adjusted by means of R_2 to within 5% limits.

The current is measured as the voltage drop across the two emitter resistors, one of the A60 differential amplifiers being used for this purpose. Since the common mode voltage is 16V, the differential amplifier is used without the two voltage followers normally employed.

Tests 3 to 8: DC level checks. During tests 0-8 the a.c. source is disabled by shorting the frequency programming capacitor terminals with the FET controlled by line C4.

Tests 9 and 10 are spares.

(It is sometimes found necessary to insert additional tests as a result of experience with early production

items. Two spare test numbers at this point in the sequence would allow two additional d.c. checks before the a.c. tests begin).

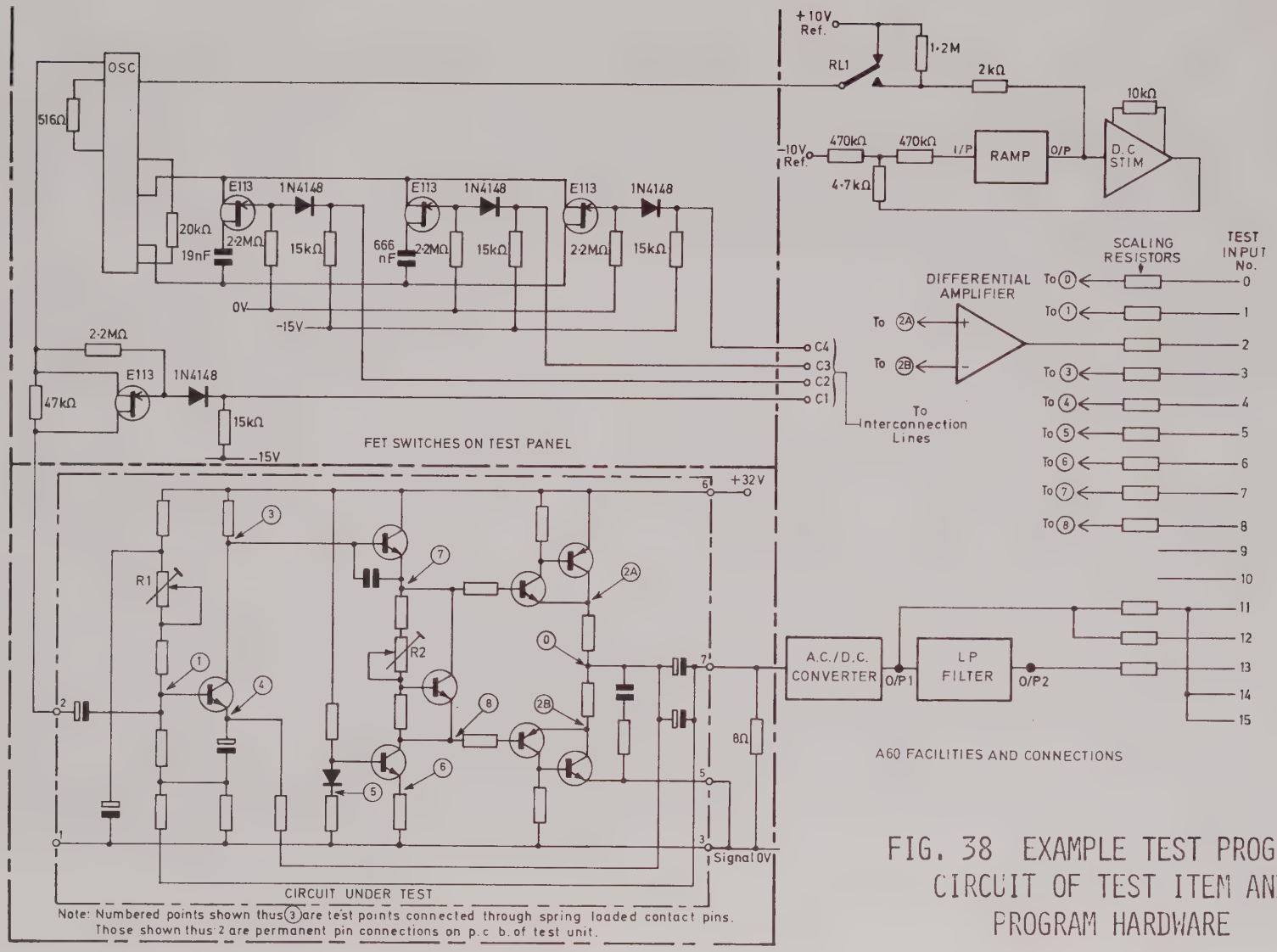
Test 11: A 365mV 1kHz signal is injected to the test item input. The output level is checked using the A60 AC/DC converter (gain test).

Test 12: A 47kΩ resistor is inserted in the input line (C1 control line released) and the AC output checked (input impedance test).

Tests 13 and 14: Gain tests at 30Hz and 20kHz.

Test 15: Frequency response test using the A60 frequency sweep facility.

Four FET switches mounted on the test panel, are used to change the frequency of the input signal, disable the a.c. source, and short-circuit the series input resistor. These switches are controlled by the test-select lines in the same manner as are tolerances and modes of operation. Four interconnection lines are used to transfer the control signals from the program board to the input-output board.



Note: Numbered points shown thus (3) are test points connected through spring loaded contact pins. Those shown thus 2 are permanent pin connections on p.c. b. of test unit.

FIG. 38 EXAMPLE TEST PROGRAM: CIRCUIT OF TEST ITEM AND PROGRAM HARDWARE

Test No.	STIMULUS			TEST SIGNAL			Nom. Volts	TOLERANCE				INTERNAL FUNCTIONS	EXTERNAL FACILITIES
	Voltage	Freq.	To	From	Via	To		Req'd	Prog'd	R_s	R_t		
0				0		0	16	2%		1.6MΩ		Semi-Auto	FET Switch C4
1				1		1	17.4	5%		1.74MΩ			FET Switch C4
2				2a, 2b	Diff. Amp.	2	0.1	5%		10kΩ		Semi-Auto	FET Switch C4
3				3		3	31.3	10%		3.13MΩ			FET Switch C4
4				4		4	16.7	5%		1.67MΩ			FET Switch C4
5				5		5	1.36	8%	7%	155.4kΩ	12MΩ		FET Switch C4
6				6		6	1.36	15%		136kΩ			FET Switch C4
7				7		7	16.7	5%		1.67MΩ			FET Switch C4
8				8		8	15.3	5%		1.53MΩ			FET Switch C4
9					Spare							Reset	
10					Spare							Reset	
11	365mV	1kHz	Pin 2	Pin 7	AC/DC Conv. O/P1	11	4.7	10%		470kΩ		Slow	FET Switches C1 & C2
12	365mV	1kHz	Pin 2	Pin 7	AC/DC Conv. O/P1	12	2.35	20%		235kΩ		Slow	FET Switch C2
13	365mV	30Hz	Pin 2	Pin 7	AC/DC Conv. O/P2	13	4.7	20%		470kΩ		Slow	FET Switches C1 & C3
14	365mV	20kHz	Pin 2	Pin 7	AC/DC Conv. O/P1	14	4.7	20%		470kΩ		Slow	FET Switch C1
15	365mV	Sweep	Pin 2	Pin 7	AC/DC Conv. O/P1	15	4.7	20%		470kΩ		Ramp & Relay No. 1	FET Switch C1
16												Reset	
⋮												⋮	
⋮												⋮	
⋮												⋮	
59												⋮	

FIG. 39 EXAMPLE TEST PROGRAM: PROGRAM SHEET

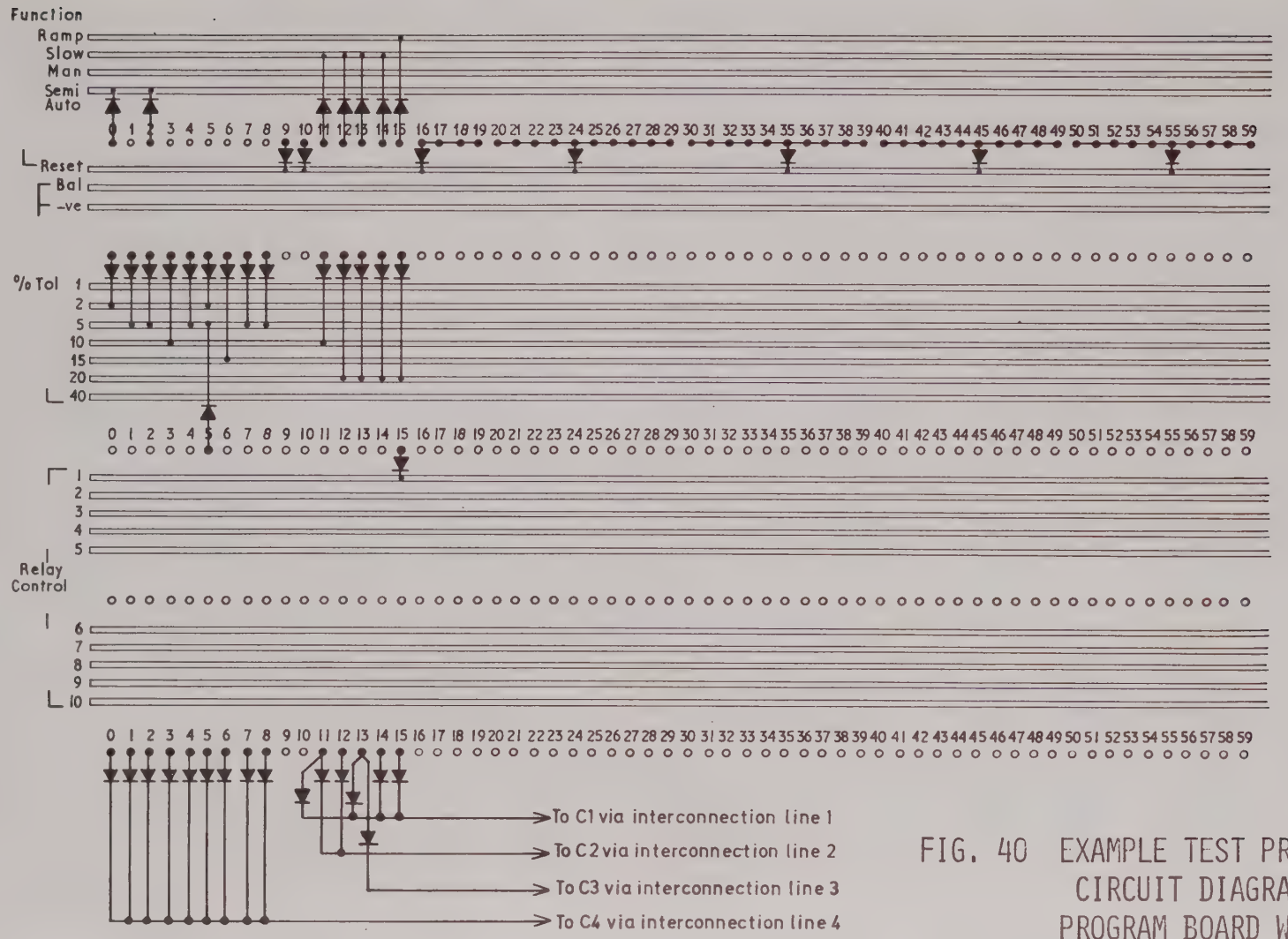

Function
Ramp
Slow
Man
Semi Auto
Reset
Bal
-ve
% Tol
1
2
5
10
15
20
40
Relay Control
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59
To C1 via interconnection line 1
To C2 via interconnection line 2
To C3 via interconnection line 3
To C4 via interconnection line 4

FIG. 40 EXAMPLE TEST PROGRAM: CIRCUIT DIAGRAM OF PROGRAM BOARD WIRING

8.0 SPECIFICATION

Number of Test Points	60
Test Panel Dimensions	405mm wide x 320mm deep ($15\frac{7}{8}$ x $12\frac{5}{8}$ in.).
Voltage Measuring Range	5mV to 500V, d.c. or a.c.
Standardised Input Level	10μA d.c.
Measurement Accuracy	Referred to standardised input ± 0.1 % ±0.03% per °C, per 10% supply variation and per 100 hours (typically 0.3% per year), ± 1 digit on readout.
Overload Protection of d.c. measuring circuit	Protected to 500V with scaling resistors greater than 10kΩ. Protected to 50mA with scaling resistors up to 10kΩ.
Pass/Fail Tolerance Limits	Programmed individually for each test; standard values ± 1, 2, 5, 10, 15, 20 & 40%; any value from 0.5% to greater than 100% obtainable by additional programming.
Test Speed	Typical program of 60 tests, 5 to 15 seconds.
Operating Modes	Auto: proceeds once through test cycle, stops on fault (use of step button after fault allows test cycle to proceed). Semi-Auto: as Auto but pauses on fault only until fault remedied. Recycle: Auto cycle repeated indefinitely until fault occurs. Manual: stepped through test cycle by push-button.

Control Outputs

60 pin connections, one per test, normally at approximately -15V, change to approximately +15V during period of test. Each can drive an external load of resistance not less than 1kΩ.

Also 10 high-grade single pole change-over relays, each separately controllable by any of above 60 control outputs.

Test Delay

Delay between selection of test point and commencement of measurement: unless otherwise programmed, approximately 40 ms. Alternatively can be programmed as any period from approximately 200ms to greater than 10 sec.

Input Converter and Amplifiers

AC/DC Converter:
Frequency range: 20Hz - 20kHz, ± 0.1dB.
Input Resistance: 10MΩ.
Input Capacitance: typically 400pF.
Conversion Gain: nominally unity referred to r.m.s. value of a sinusoidal input.
Output Voltage Error: ± 20mV max.* at 1kHz.
Output Polarity: Positive
Maximum Input Voltage: ± 10V peak.

AC Amplifiers (2 off):
Frequency Range: 20Hz - 20kHz, ± 0.1dB.
Input Resistance: 10MΩ.
Input Capacitance: typically 350pF.
Voltage Gain: 10 ± 0.2%* at 1kHz.
Maximum Output: ± 10V peak.
Noise: typically 70μV r.m.s. in 100kHz bandwidth, referred to input.

High-Impedance AC/DC Amplifier:
Frequency Range: d.c. -20kHz, (slew rate limitation corresponds to a maximum input of ± 1.5V peak at 2kHz).
Input Resistance: 1000 MΩ.
Input Capacitance: typically 350pF.
Voltage Gain at d.c.: unity, ± 0.2%*.
Maximum Input: ± 10V peak a.c. or d.c., subject to slew rate limitation.
Input Current: < 1nA.
Temperature Coefficient of offset voltage: ± 50μV/°C.

AC/DC Differential Amplifiers (4 off, each comprising 2 unity-gain amplifiers and a low-input-impedance differential amplifier. These can be used separately or in combination as required):

Amplifiers Cont'd	Frequency Range: d.c. -20kHz, ± 0.1dB, (slew rate limitation corresponds to a maximum input of ± 1.5V peak at 20kHz). Input Resistance: 10MΩ. Input Capacitance: typically 350pF either side to ground. Voltage Gain: unity, ± 0.2%*. Maximum Input: ± 10V peak, a.c. or d.c., subject to slew rate limitation. Common-mode rejection: > 60dB. Input Current: < 250nA.
Test Unit Power Supplies	2 off, independent, floating, stabilised d.c. supplies, can be used separately, in series or in parallel. Output Voltage: programmable 5V to 18V (each supply). Output Current: internally limited to approx. 0.5A (each supply). Voltage Accuracy: ± 0.2%*, -0.1% per 100mA load.
Additional Power Supplies	+15V and -15V d.c. stabilised, maximum permissible load approximately 100mA.
Reference Voltage Supplies	+10V and -10V d.c. available as close-tolerance, highly stable reference voltage sources. Voltage Accuracy: ± 0.1%. Maximum Load: 5mA.
Stimuli	A.C.: frequency programmable 20Hz - 20kHz. Frequency accuracy ± 1%. Sine-wave output: programmable 0-10V peak, voltage accuracy ± 0.2dB*. Square-wave output: leads sinusoidal output by 90°, approximately 15V pk/pk e.m.f. from 4.7kΩ source. Triangular-wave output: in phase with sinusoidal output, approximately 20V pk/pk into 10kΩ external load. Negative & positive d.c. outputs, each proportional to A.C. Stimulus frequency, also available. Ramp: voltage sweep 0 to > +10V. Duration: programmable, 10ms to at least 100 sec.

Stimuli Cont'd	D.C.: programmable -10V to +10V. Voltage Accuracy: ± 0.2%* ± 30μV/°C. Output Impedance: < 1Ω. Output Load Resistance: ≮ 2kΩ. Output Current: ≯ 20mA.
Sweep-Frequency Facility	Produced by combination of A.C. Stimulus Source with Ramp Generator.
Monostable	Programmable to produce defined time intervals of 10μs to 10 sec.
Sample-and-Hold	Compatible with monostable. Input Voltage Range: -10V to +10V. Input slew rate: 10V/ms.
Output to External Printer	BCD: Test number (2 decades). % deviation (3 decades, ± sign, and '100'). Tolerance programmed (2 decades). 'Fault' Print command (logic '1' and '0' pulses). The above are TTL-compatible, referred to -15V. D.C. outputs at -15V and -10V give a 5V, 50mA supply for external logic.
Power Requirements	2 models available: A60-1: 200 - 250V, 50Hz (fuse rating: surge-proof, 1A). A60-2: 100 - 130V, 60Hz (fuse rating: surge-proof, 2A). Consumption approximately 150VA.
Dimensions	Width: 420mm ($16\frac{1}{2}$ in) Height: 162mm ($6\frac{3}{8}$ in) Depth: 570mm ($22\frac{1}{2}$ in)
Weight	Approximately 11kg. (25lb).

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* These figures apply at 20°C. Temperature variations of ± 10°C will not cause more than x2 increase. A similar relaxation of accuracy applies for stability (one year).

MP MASTER
MA24489

Wilmot Breeden Electronics

Ferrograph Rendar Wayne Kerr

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